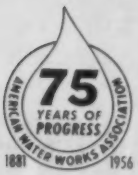
JUNE 1956



Journal

VOL. 48 • NO. 6

AMERICAN WATER WORKS ASSOCIATION

In this issue

Automatic Filter Plant in Scotland	Denholm
Conductivity and Coagulation	Babcock, Knowlton
Pump System Analysis	Triay
Fire Protection Problems	Krieger
Radioactive Fallout	Eisenbud, Eliassen, Lauderdale, Ridenour, Armbruster
Coxsackie Virus Survival	Clarke, Stevenson, Kabler
Polyphosphate Threshold Action	Corsaro, Ritter, Hrubik, Stephens
Estimating Flow-Through Time	Taras
Activated Silica Production	Andrews, Burdett
Corrosion Manual	Hertzberg
Effect of Iron on Zeolite	Will
Friction Losses in Service Lines and Fittings	Arnold, Carns

HIGH QUALITY HYDRANT AT LOWEST COST

The R. D. Wood Standard Swivel Joint Hydrant with or without breakable flange and stem coupling

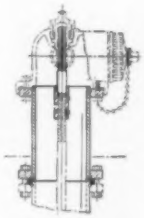
The R. D. Wood Standard Swivel Joint Hydrant is designed to provide maximum strength and reliability at lowest possible cost. Internal friction, which can lower pressure, is reduced to the minimum, well below A.W.W.A. specifications. Changes of diameter are carefully rounded and nozzleways are scientifically tapered.

All Bronze Stuffing Box

Sound and simple in construction. It cannot rust or corrode. Hydrant operating thread can be greased or oiled by unscrewing one small plug.

Extension Piece

Can be inserted between hydrant head and barrel or between barrel and elbow. Installation does not require shutting off water supply.



Breakable Flange and Stem Coupling

Available at slight additional cost are this specially designed flange in the standpipe and a frangible coupling in the hydrant stem. A heavy blow that would ordinarily break the hydrant will snap the ring in the flange and the coupling in the stem. Both can be replaced quickly and inexpensively. No digging is necessary.

Available with standard types of pipe connections—bell, *mechanical joint*, flange, universal or screw.

R. D. WOOD COMPANY

Public Ledger Building, Independence Square, Philadelphia 5, Pa.

Manufacturers of "Sand-Spun" Pipe (centrifugally cast in sand molds) and R. D. Wood Gate Valves

Journal

AMERICAN WATER WORKS ASSOCIATION

2 PARK AVE., NEW YORK 16, N.Y. • Phone: MUrray Hill 4-6686

June 1956

Vol. 48 • No. 6

Contents

Automatic Operation at the Broadside Filter Plant in Scotland
ERIC W. DENHOLM 597

Conductivity-Difference Control of Chemical Coagulation
R. H. BABCOCK & K. F. KNOWLTON 622

Pump System Analysis and Planning Methods Used in the Los Angeles City Water System ..... ROLAND TRIAY JR. 629

Directors Oppose Return of Used Water to Mains 653

Fire Protection Problems With Undersized Mains ..... HARRY L. KRIEGER 654

Water Utility Safety in Seattle 658

Monitoring Network for Measuring Radioactive Fallout ..... MERRIL EISENBUD 659

Radioactive Fallout in Water Supply at Portland, Me.
ROLF ELIASSEN & ROBERT A. LAUDERDALE 665

Effect of High-Level Gamma Radiation on Disinfection of Water and Sewage
GERALD M. RIDENOUR & EDWARD H. ARMBRUSTER 671

Reprints Available 676

Survival of Coxsackie Virus in Water and Sewage
NORMAN A. CLARKE, ROBERT E. STEVENSON & PAUL W. KABLER 677

Mechanism of Polyphosphate Threshold Action
GERALD CORSARO, H. S. RITTER, WILLIAM HRUBIK & HOWARD L. STEPHENS 683

Estimation of Flow-Through Time by the Continuous-Dose Method
MICHAEL J. TARAS 700

Continuous Production of Activated Silica With Low-CO_2 Gases
R. V. ANDREWS & JOE W. BURDETT 713

Correction—Snail and Clam Infestation (WILLIAM MARCUS INGRAM) 718

Suggested Nontechnical Manual on Corrosion for Water Works Operators
LEE B. HERTZBERG 719

Report on the Effect of Iron on High-Capacity Zeolite ..... EDGAR G. WILL 739

Friction Losses in Service Lines and Fittings ..... GERALD E. ARNOLD 744

Discussion ..... JAMES G. CARNS JR. 752

Departments

Officers and Directors	*2 P&R*	Service Lines	*50 P&R*
Coming Meetings	*6 P&R*	Condensation	*62 P&R*
Percolation and Runoff	*35, 76 P&R*	New Members	*82 P&R*
Conference Statistics	*40 P&R*	Index of Advertisers' Products	*90 P&R*

HARRY E. JORDAN, *Secretary*

ERIC F. JOHNSON, *Asst. Secy.—Publications* LAWRENCE FARBER, *Managing Editor*

DONALD A. NELSEN, *Assistant Editor* ALBERT NEWGARDEN, *Assistant Editor*

Journal AWWA is published monthly at Prince & Lemon Sts., Lancaster, Pa., by the Am. Water Works Assn., Inc., 2 Park Ave., New York 16, N.Y., and entered as second class matter Jan. 23, 1943, at the Post Office at Lancaster, Pa., under the act of Aug. 24, 1912. Accepted for mailing at a special rate of postage provided for in paragraph (d-2), Section 34.40, P. L. & R. of 1948. Authorized Aug. 6, 1918. $7.00 of members' dues are applied as a subscription to the JOURNAL; additional single copies to members—60 cents; single copies to non-members—85 cents. Indexed annually in December; and regularly by *Industrial Arts Index* and *Engineering Index*. Microfilm edition (for JOURNAL subscribers only) by University Microfilms, Ann Arbor, Mich.

© 1956, by the American Water Works Association, Inc. Made in U.S.A.

AWWA Officers and Directors

President	PAUL WEIR	*Past-President*	F. C. AMSBARY JR.
Vice-President	FRED MERRYFIELD	*Treasurer*	WILLIAM W. BRUSH
Ch. W.W. Practice Com.	LOUIS R. HOWSON	*Secretary*	HARRY E. JORDAN
Ch. W.W. Admin. Com.	WENDELL R. LADUE	*Exec. Asst. Secretary*	RAYMOND J. FAUST
Ch. Publication Com.	E. SHAW COLE	*Asst. Secretary-Pub.*	ERIC F. JOHNSON

Officers of the Sections

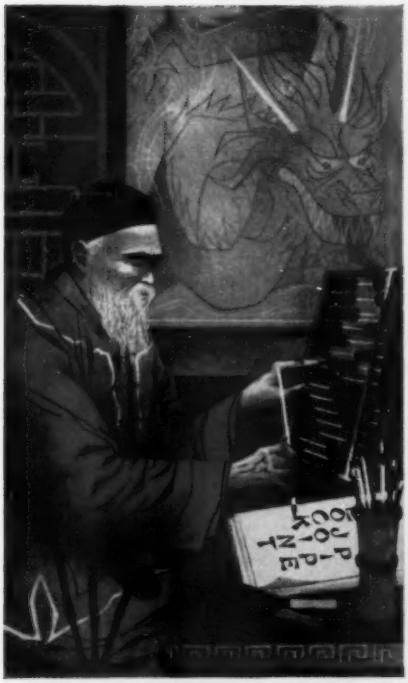
Section	*Director*	*Chairman*	*Vice-Chairman*	*Secretary-Treasurer*
Alabama-Miss.	E. M. Stickney	W. U. Quinby	H. L. Burns	Irving E. Anderson
Arizona	Dario Travaini	M. V. Ellis	Q. M. Mees	H. C. Bigglestone
California	B. S. Grant	W. R. Seeger	M. J. Shelton	H. J. Ongerth
Canadian	C. G. R. Armstrong	V. A. McKillop	H. P. Stockwell	A. E. Berry
Chesapeake	David Auld	B. L. Werner	R. W. Haywood	C. J. Lauter
Cuban	G. A. Bequer H.	J. A. Vila	M. F. DeVera	L. H. Daniel
Florida	W. W. Gillespie	J. R. Kelly	Stanley Sweeney	J. D. Roth
Illinois	E. E. Alt	G. L. Davis	C. L. Baylor	D. W. Johnson
Indiana	C. E. Williams	C. E. Robbins	R. G. Rinehart	R. J. Becker
Iowa	C. W. Hamblin	D. L. Bragg	P. H. Morgan	J. J. Hail
Kansas	H. W. Badley	B. H. Van Blarcum	R. F. Bluejacket	H. W. Badley
Kentucky-Tenn.	Elmer Smith	J. J. Davis	R. A. Fischer	J. Wiley Finney Jr.
Michigan	E. D. Barrett	C. R. Erickson	W. E. Smith	T. L. Vander Velde
Missouri	H. O. Hartung	E. G. Lee	F. J. McAndrew	W. A. Kramer
Montana	C. W. Eyer	B. F. Chestnut	R. G. Cronin	A. W. Clarkson
Nebraska	Bert Gurney	C. L. Fisher	George Beard	J. E. Olsson
New England	E. S. Chase	J. H. Robinson	F. J. Thiery	J. E. Revelle
New Jersey	C. J. Alfke	Maurice Brunstein	H. M. Ohland	C. B. Tygert
New York	J. G. Copley	F. D. Behan	L. J. Griswold	Kimball Blanchard
North Carolina	W. M. Franklin	R. S. Phillips	C. W. Mengel	W. E. Long Jr.
North Central	L. N. Thompson	L. H. Coult	H. H. Behlmer	L. N. Thompson
Ohio	C. E. Beatty	D. D. Heffelfinger	M. W. Tatlock	M. E. Druley
Pacific Northwest	E. J. Allen	C. R. Harlock	H. J. Donnelly	Fred D. Jones
Pennsylvania	L. D. Matter	B. F. Johnson	P. W. Miller	L. S. Morgan
Rocky Mountain	G. J. Turre	J. O. Jones	Harry Barnes	J. W. Davis
Southeastern	Sherman Russell	C. C. Lanford	L. E. Wallis	N. M. deJarnette
Southwest	J. R. Pierce	J. H. O'Neill	H. R. Street	L. A. Jackson
Virginia	E. C. Meredith	H. F. Knoell	W. W. Anders	J. P. Kavanagh
West Virginia	W. S. Staub	C. B. Whitlock	C. C. Coffield	H. W. Hetzer
Wisconsin	J. C. Zufelt	B. J. Hartman	J. E. Kerslake	

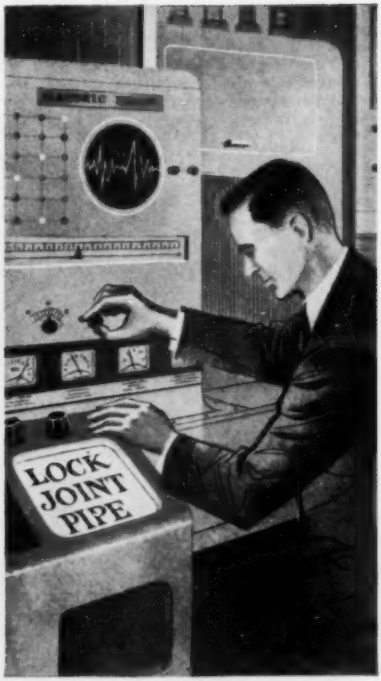
Directors Representing the Water and Sewage Works Manufacturers Assn.

CARL N. BROWN ROBERT F. ORTH R. S. RANKIN

Officers of the Divisions

Division	*Chairman*	*Vice-Chairman*	*Secretary*
Water Distribution	H. W. Niemeyer	E. J. Allen	J. B. Ramsey
Water Purification	H. H. Gerstein	P. D. Haney	Sherman Russell
Water Resources	H. C. Barksdale	C. H. Bechert	J. W. Cramer
Water Works Management	L. W. Grayson	W. W. DeBerard	J. D. Kline





NO MATTER HOW YOU FIGURE IT...

When you undertake the purchase of a new pipeline for your water supply system, do you figure from the financial angle—low first cost, economical installation and a long life for your investment?

Or are you more interested in the construction of the line—minimum excavation, easy assembly, and water-tight joints in a pipe strong enough to withstand high pressures and heavy external loads?

Then, again, your specialty may be maintenance. In that case you probably figure minimum repairs through freedom from breaks and leaks to be of paramount importance.

Or is your main concern with operation? If so, you no doubt figure permanent high carrying capacity, low pumping costs and trouble-free service to be vital.

Still, *no matter how you figure* it, your best answer will always be LOCK JOINT CONCRETE PRESSURE PIPE, because it most nearly approximates the ideal pressure pipe for water works systems.

LOCK JOINT PIPE CO.

East Orange, New Jersey

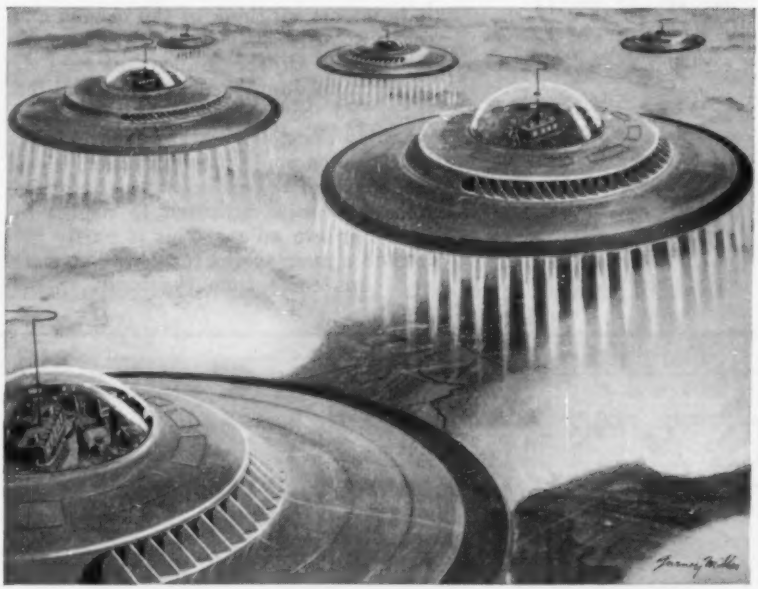
Sales Offices: Chicago, Ill. • Columbia, S. C. • Denver, Col. • Detroit, Mich. • Hartford, Conn. • Kansas City, Mo.

Pressure • Water • Sewer • REINFORCED CONCRETE PIPE • Culvert • Subaqueous

LIST OF ADVERTISERS

	P&R PAGE
Ace Pipe Cleaning, Inc.	50
Alabama Pipe Co.	—
Alco Products, Inc.	—
Allis-Chalmers	74, 75
American Agricultural Chemical Co.	44
American Brass Co., The	12
American Cast Iron Pipe Co.	19
American Concrete Pressure Pipe Assn.	30
American Cyanamid Co., Heavy Chemicals Dept.	88
American Pipe & Construction Co.	87
American Well Works	97
Anthracite Equipment Corp.	64
Armco Drainage & Metal Products, Inc.	63
Badger Meter Mfg. Co.	20, 21
Barrett Div.	51
Bethlehem Steel Co.	8
B-I-F Industries, Inc.	43, 84, 90
Buffalo Meter Co.	9
Builders-Providence, Inc. (Div., B-I-F Industries)	43, 90
Byron Jackson Div., Borg-Warner Corp.	—
Calgon, Inc.	91
Carborundum Co., The	53
Carson, H. Y., Co.	48
Carus Chemical Co.	62
Cast Iron Pipe Research Assn., The	46, 47
Centriline Corp.	—
Chain Belt Co.	79
Chapman Valve Mfg. Co.	15
Chicago Bridge & Iron Co.	—
Clow, James B., & Sons	26, 85
Cochrane Corp.	—
Cole, R. D., Mfg. Co.	72
Crane Co.	—
Darley, W. S., & Co.	64
Darling Valve & Mfg. Co.	—
De Laval Steam Turbine Co.	23
DeZurik Shower Co.	80
Dorr-Oliver Inc.	Cover 3
Dresser Mfg. Div.	81
Eddy Valve Co.	26, 85
Electro Rust-Proofing Corp.	—
Ellis & Ford Mfg. Co.	48
Everson Mfg. Corp.	—
Fischer & Porter Co.	95
Flexible Inc.	—
Ford Meter Box Co., The	6, 7
Foster Engineering Co.	52
Foxboro Co.	49
Frontier Chemical Co.	—
General Chemical Div., Allied Chemical & Dye Corp.	71
General Filter Co.	67
Golden-Anderson Valve Specialty Co.	70
Graver Water Conditioning Co.	—
Greenberg's, M., Sons	—
Hammarlund Mfg. Co.	—
Hammond Iron Works	89
Harco Corp.	—
Hays Mfg. Co.	18
Hersey Mfg. Co.	83
Hungerford & Terry, Inc.	86
Hydraulic Development Corp.	16
Industrial Chemical Sales Div., West Virginia Pulp & Paper Co.	33
Inertol Co., Inc.	—
Infilco Inc.	37
Iowa Valve Co.	26, 85
Johns-Manville Corp.	—
Johnson, Edward E., Inc.	—
Jones, John Wiley, Co.	—
Keasbey & Mattison Co.	14
Kennedy Valve Mfg. Co., The	—
Klett Mfg. Co.	42
LaMotte Chemical Products Co.	78
Layne & Bowler, Inc.	10
Leadite Co., The	Cover 4
Leopold, F. B., Co.	76
Limitorque Corp.	68
Lock Joint Pipe Co.	3
Ludlow Valve Mfg. Co.	28
M & H Valve & Fittings Co.	31
Millipore Filter Corp.	—
Minneapolis-Honeywell Regulator Co.	73
Monolith Portland Midwest Co.	66
Mueller Co.	13
National Cast Iron Pipe	26, 85
National Water Main Cleaning Co.	45
Neptune Meter Co.	34
Northern Gravel Co.	82
Omega Machine Co. (Div., B-I-F Industries)	—
Pekrul Gate Div. (Morse Bros. Machinery Co.)	—
Permutit Co.	24, 25
Phelps Dodge Refining Corp.	—
Philadelphia Gear Works, Inc.	68
Philadelphia Quartz Co.	—
Pittsburgh-Des Moines Steel Co.	—
Pittsburgh Equitable Meter Div. (Rockwell Mfg. Co.)	98
Pollard, Jos. G., Co., Inc.	41
Portland Cement Assn.	—
Pratt, Henry, Co.	—
Proportioneers, Inc. (Div., B-I-F Industries)	84
Reed Mfg. Co.	—
Reilly Tar & Chemical Corp.	—
Rensselaer Valve Co.	29
Roberts Filter Mfg. Co.	—
Rockwell Mfg. Co.	98
Ross Valve Mfg. Co.	—
Schleicher, Carl, & Schuell	—
Simplex Valve & Meter Co.	39
Skinner, M. B., Co.	78
Smith, A. P., Mfg. Co., The	65
Smith, S. Morgan, Co.	61
Smith-Blair, Inc.	—
Spring Load Mfg. Corp.	27
Steel Plate Fabricators Assn.	54
Stuart Corp.	—
Tennessee Corp.	17
Trelleborgs Gummifabriks AB	11
Trinity Valley Iron & Steel Co.	22
U.S. Pipe & Foundry Co.	5
E. H. Wachs Co.	—
Walker Process Equipment, Inc.	—
Wallace & Tiernan Inc.	32
Well Machinery & Supply Co.	69
Western Materials Co.	—
Wheeler, C. H., Mfg. Co.	93
Wood, R. D., Co.	Cover 2
Woodward Iron Co.	—
Worthington-Gamon Meter Div.	77

Directory of Professional Services—pp. *55-60 P&R*



GIANT gravity-defying sentinels of high strength alloys, armed with nuclear weapons, may be able to hover near centers of aggression ready at an instant's notice to drop destruction that will make war too deadly to risk.

100 years from now...

WE MAY MAKE WAR IMPOSSIBLE!

Scientists, looking ahead, envisage a fabulous future...full of wonderful new products that will bring civilization a whole new era of progress. But, even then, our gas and water will still flow through the same dependable cast iron pipe being laid now.

Here's proof! Today, more than 60 American cities and towns are being efficiently served by the same cast iron water and gas mains laid over 100 years ago. What's more, modernized cast iron pipe...centrifugally cast and quality-controlled ...is even stronger, tougher, more serviceable.

U. S. Pipe is proud to be one of the leaders in a forward-looking industry whose service to the world is measured in centuries.

U.S. cast iron PIPE

CAST IRON

U. S. PIPE AND FOUNDRY COMPANY, General Office: Birmingham 2, Alabama

A WHOLLY INTEGRATED PRODUCER FROM MINES AND BLAST FURNACES TO FINISHED PIPE.

Fordin' Along...

It is seldom we think of the oceans and seas as vast settling basins, but such they are. All the millions of tons of silt brought down by rivers are deposited there and the one-way process has been going on since first water began to flow. Unlike man-made basins, there is no cleaning and the sediment on the ocean floor has been measured to depths of well over two miles. This is partly the insoluble remains of ocean life but most of it has come from the lands of the earth.

Coming Meetings

AWWA SECTIONS

Sep. 12–14—New York Section, at Sagamore Inn, Bolton Landing, Lake George. Secretary, Kimball Blanchard, Rensselaer Valve Co., c/o Ludlow Valve Co., 11 W. 42nd St., New York 17.

Sep. 12–14—Michigan Section, Kalamazoo. Secretary, T. L. Vander Velde, Chief, Water Supply Section, Michigan Dept. of Health, Lansing 4.

Sep. 12–14—North Central Section, at Hotel Lowry, St. Paul, Minn. Secretary, Leonard N. Thompson, Gen. Mgr., Water Dept., St. Paul 2, Minn.

Sep. 17–19—Kentucky-Tennessee Section, at Hotel Patten, Chattanooga, Tenn. Secretary, J. W. Finney Jr., 553 S. Limestone St., Lexington, Ky.

Sep. 19–21—Ohio Section, at Commodore Perry Hotel, Toledo. Secretary, M. E. Druley, Dayton Power & Light Co., Wilmington.

Sep. 26–28—Wisconsin Section, at Stoddard Hotel, La Crosse. Secretary, L. A. Smith, Supt., Water & Sewerage, City Hall, Madison 3.

Sep. 30–Oct. 2—Missouri Section, at Hotel Governor, Jefferson City. Secretary, W. A. Kramer, Rm. 3, 6th Floor, State Office Bldg., Jefferson City.

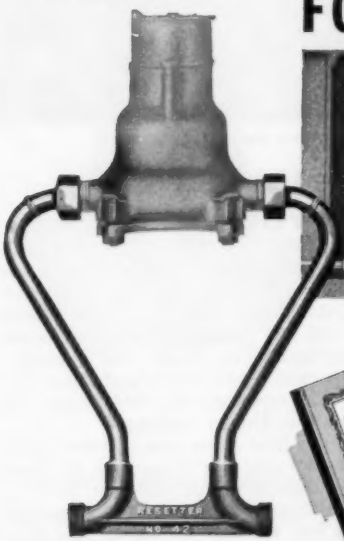
Oct. 14–17—Southwest Section, at Marion Hotel, Little Rock, Ark. Secretary, Leslie A. Jackson, Mgr.-Engr., Municipal Water Works, Robinson Memorial Auditorium, Little Rock, Ark.

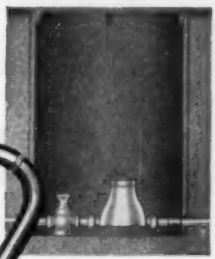
Give Your METER READER a Break!

Save hours of meter reading time and get more dependable readings by bringing your meters UP with Ford Resetters.

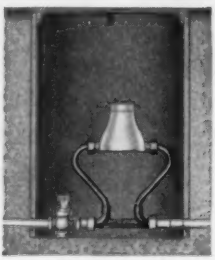
These handy, easy to install, settings are made to raise meters from 6″ to 30″ or more above the old position. Meters are then cleaner and far more accessible.

FORD RESETTERS





BEFORE



AFTER

Send now for details and complete new Ford catalog No. 56—FREE

THE FORD METER BOX COMPANY, INC.

FOR BETTER WATER SERVICES **FORD**

Wabash, Indiana

Installing 36-in. tar-enameled steel pipe in a wooded area northwest of Worcester.

20,000-ft steel main installed in Worcester

One of the biggest water-supply projects to be completed in New England in 1955 was the Worcester, Mass., high-pressure line. The design working pressures are 160 psi for the 36-in. ID section and 190 psi for the 30-in. ID section.

The steel main extends somewhat over 20,000 ft from the pumping station at Holden Reservoir No. 2 to a point near Indian Lake, where it connects with Indian Hill Reservoir. Its high capacity and great reserve strength make the line an important source of water for the present and future needs of industrial Worcester.

The line is 36 in. ID for some 14,300 ft from the pumping station to Grove Street, where it is reduced to 30 in. ID. Bethlehem supplied the pipe in easy-to-install 40-ft lengths, coated and lined with coal-tar enamel, and protected with felt and paper wrappings. Every length was hydrostatically tested in our shop in accordance with AWWA specifications. Field joints were made with Dresser couplings.

If you have a new large-diameter line in mind, we urge you to consider the many advantages of welded steel pipe. No other material can match steel pipe for strength, long life, resistance to damage, leak-proof joints and ease of installation. May we give you more information? Please contact the Bethlehem sales office nearest you.

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. *Export Distributor:* Bethlehem Steel Export Corporation

BETHLEHEM STEEL

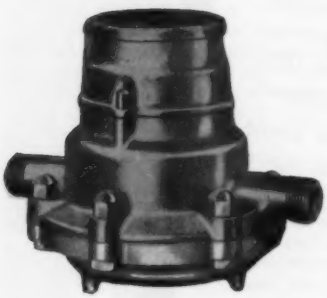
BETHLEHEM STEEL

The Safest Meter to Buy is AMERICAN

Because:

they're so easy to maintain

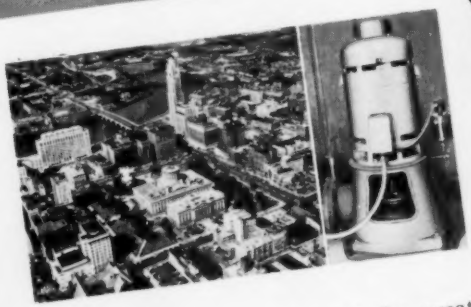
"American Meters reduce work in the meter shop because they are built so well and so simply there's hardly any maintenance. That's why we play safe and buy American."

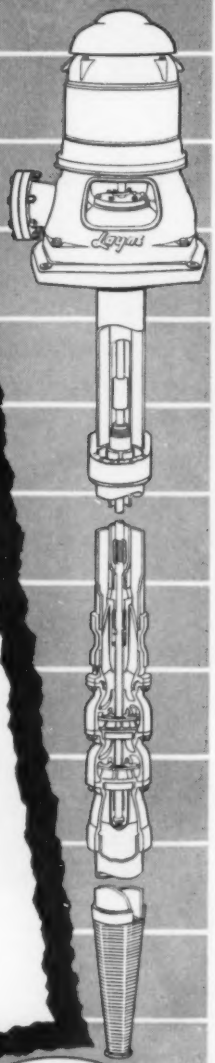


American Meters everywhere are proving their built-in quality by operating so free of trouble year after year. Work in the meter shop is made easier. Individual parts are interchangeable in old or new meters. Yes, the repairman who knows, endorses American, the safest meter to buy.

BUFFALO METER CO. 2914 MAIN STREET BUFFALO 14, N. Y.

Keeping Supply... Ahead of Demand





As Columbus, capital city of the great state of Ohio, grew—so did its demand for water.

Six Layne drilled wells and six Layne vertical turbine pumps with a potential capacity of ten million gallons of water per day now serve the city's eastern section. This provides adequate supply for future growth.

Hundreds of municipalities rely on Layne for any service relating to ground water.

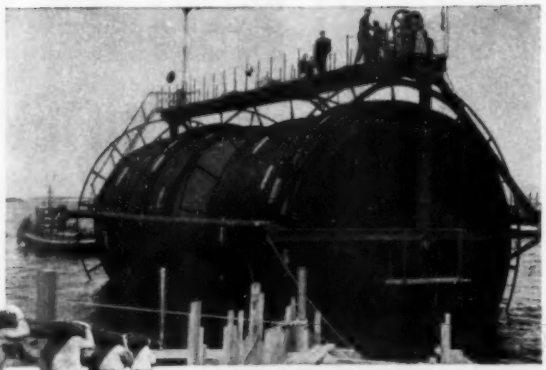
LAYNE & BOWLER, INC.
MEMPHIS
General Offices and Factory

LAYNE ASSOCIATE COMPANIES THROUGHOUT THE WORLD

Layne

Water Wells • Vertical Turbine Pumps • Water Treatment

The hose was laid down in its watery bed from an enormous reel.



Six miles of rubber hose on ocean floor provides Swedish town with fresh water

A bathing resort with water worries

For a long time, the town of Lysekil on the Swedish West Coast had been troubled by a water-supply problem, which grew more serious from year to year. The worst time of all was during the summer, when tourists usually come in hordes to enjoy the bathing.

Problem: Laying a pipe on the ocean floor

The closest source of supply was a lake on a large island not far from Lysekil, which meant that water would have to be piped across the ocean floor. A metal pipe wouldn't withstand the corrosion of salt water — some other material was needed.

Trelleborg enters the picture

Where other materials are inadequate, rubber often proves the best solution. In this case, the hose had to be of special, extra-sturdy design in rubber of just the right grade. It must, for instance, leave no taste or smell in the drinking water.

Good old experience comes in handy

This was certainly not the first time that Trelleborgs Gummifabrik was called upon to supply rubber hose for this kind of service. However, the Lysekil project was the biggest it had ever tackled.

With our rich background of experience to work from, we were able to manufacture a hose six miles long and six inches in diameter in the space of a few months.

No more water problems now!

The people of Lysekil are more than satisfied with their new hose line, which is giving them all the water they had so long waited for. The installation is big enough to supply a population of 9,000.

Have you similar rubber problems? Consult us!

Our ample facilities and know-how are at your service. Are you planning any hose projects, large or small? Just ask us — we are always delighted to contribute towards a solution.

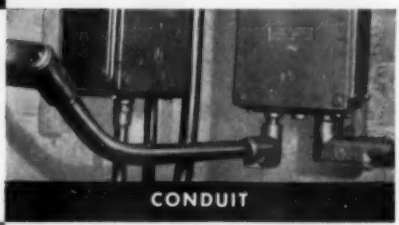
TRELLEBORG

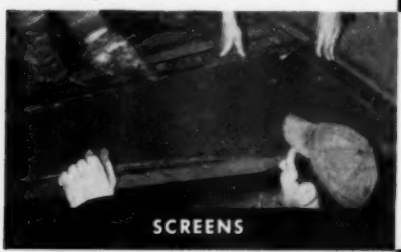
TRELLEBORGS GUMMIFABRIKS AB • TRELLEBORG • SWEDEN

Proved Protection against Corrosion with EVERDUR

Everdur is Readily Fabricated. Everdur alloys are available for hot or cold working, welding, free-machining, forging and casting—and can be supplied in plates, sheets, rods, bars, wire, tubes, electrical conduit, and casting ingots.

Everdur* Resists Corrosion. Installations of Everdur sewage treatment and waterworks equipment in the United States have been in service without replacement for 20 years and longer—evidence of Everdur's ability to resist corrosion common to these operations. *Reg. U. S. Pat. Off.





Write for Publication E-11, "Everdur Copper-Silicon Alloys for Sewage and Waterworks Equipment"—or for assistance of the Technical Department in selecting the correct material for your equipment. Address: The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont. 56130

Everdur is Tough. Everdur, Anaconda's group of copper-silicon alloys, also possesses high physical strength and resistance to wear and abrasion—so that wrought equipment can be designed with lighter weight.

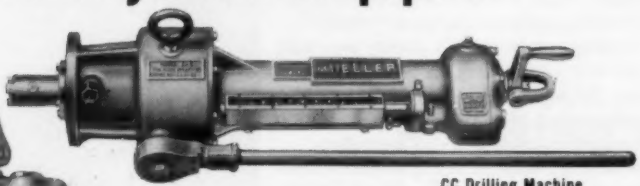
ANACONDA®

COPPER-SILICON ALLOYS

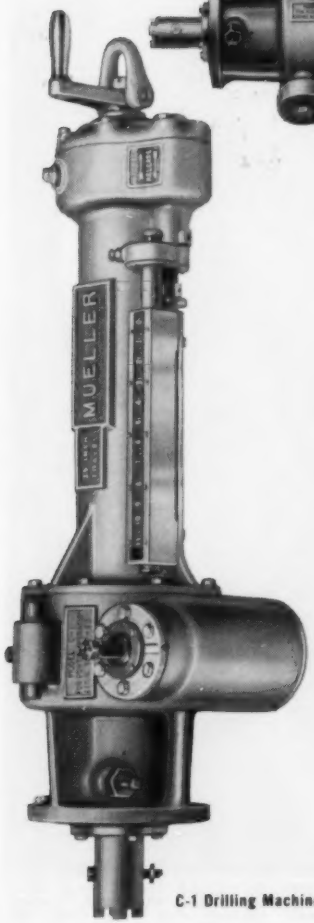
STRONG • WELDABLE
WORKABLE
CORROSION-RESISTANT

MUELLER

Make cuts 2" through 12" in any kind of pipe!



CC Drilling Machine



C-1 Drilling Machine

MUELLER Drilling Machines offer:

- 25" Boring bar travel
- Hand or power operation
- Air or gasoline power units
- Automatic or manual feed
- Standard feed indicator
- Pressures to 500 p.s.i. at 100° F.
- Temperatures to 500° F. at 250 p.s.i.

Install control valves, connect branch mains and make other water works installations – all under pressure.

Contact your Mueller Representative or write direct for complete information.

MUELLER CO.

Dependable Since 1857

MAIN OFFICE & FACTORY DECATUR, ILLINOIS

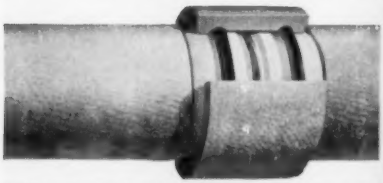
TAX SAVINGS "AROUND THE BEND"

with K&M "CENTURY"® ASBESTOS-CEMENT PRESSURE PIPE

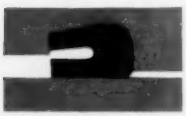
Cutting construction and maintenance costs means tax savings for Madison Park, N.J. And low cost is practically inherent in "Century" Asbestos-Cement Pressure Pipe and "Fluid-Tite" Couplings. The light weight makes for easy, inexpensive transportation and handling, while "Fluid-Tite" Couplings allow quick assembly even with unskilled labor, slashing laying time and cost. Its non-corrosive feature means long underground life. And "Century" Pipe is non-tuberculating and non-electrolytic . . . the bore is always clean and smooth. Pumping pressures remain continuously stable.

Find out how "Century" Pipe and "Fluid-Tite" Couplings can reduce construction and maintenance costs for you. Write today for full details.

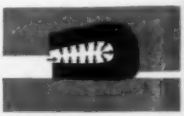
and "FLUID-TITE"® COUPLINGS*



K&M's exclusive "Fluid-Tite" Coupling design allows pipe to slide into coupling easily. Water pressure automatically expands the rings. *Patent applied for

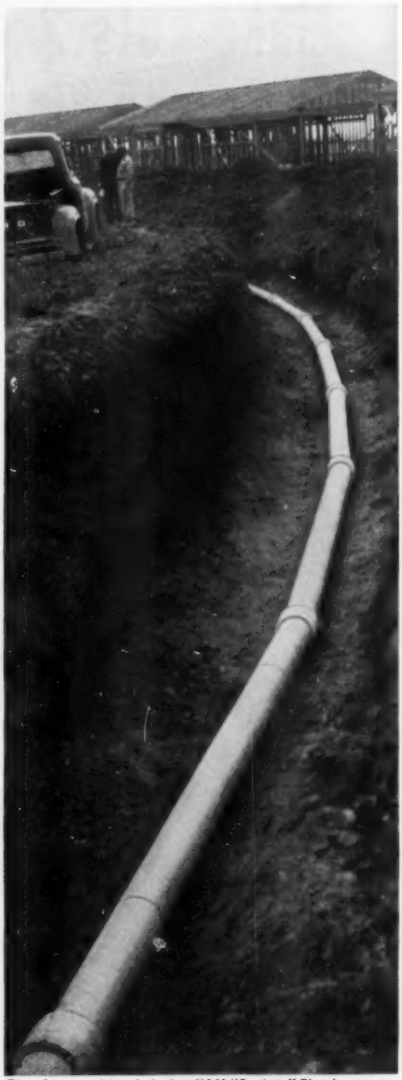


"Fluid-Tite" sealing rings compress, permitting pipe to enter coupling easily.



Water pressure expands rings; the higher the pressure, the tighter the seal.

"Century" Pipe and "Fluid-Tite" Couplings meet A.W.W.A., A.S.T.M., and Federal specifications and are approved by Underwriters' Laboratories, Inc.



There's no problem in laying K&M "Century" Pipe in a curve. In this Madison Park housing development, "Century" Asbestos-Cement Pressure Pipe with "Fluid-Tite" Couplings allow 5° deflection but fit together easily, requiring no skilled labor for assembly.

KEASBEY & MATTISON COMPANY • AMBLER • PENNSYLVANIA

K&M best in asbestos

For Top Performance
IT'S

On the Beam

Chapman's Beamed Waterway Gate Valve

Add it all up. In the partly open position, six to ten times more bearing contact surface than with any other double disc parallel seat or square bottom gate valve. Long wearing bronze bearing surfaces on beams and downstream discs. Smooth operation. Tight seats. Practically no leakage. Chapman craftsmanship throughout.

It all adds up to just one thing. For Filtration Plants, for Wash Water Valve Service, or other similar limited throttling conditions, your surest answer is Chapman's Beamed Waterway Gate Valve. For top performance . . . decades of good useful life with lowest maintenance costs . . . it's really on the beam.

In all standard sizes. Operation: by any desired method. Described in full in Chapman's Catalog No. 45. Write for your copy today.

THE CHAPMAN VALVE MFG. CO.

INDIAN ORCHARD, MASSACHUSETTS

YOU WERE DOING THIS

WHEN THE FIRST HYDRO-TITE JOINTS WERE BEING POURED -

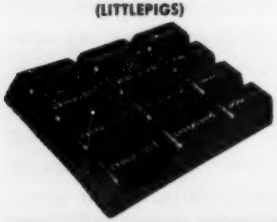
HYDRO-TITE
(POWDER)

HYDRO-TITE

(POWDER)

For over 40 years HYDRO-TITE has been faithfully serving water works men everywhere. Self-caulking, self-sealing, easy-to-use. Costs about 1/5 as much as lead joints. Packed in 100 lb. moisture-proof bags.

HYDRO-TITE
(LITTLEPIGS)



HYDRO-TITE

(LITTLEPIGS)

The same dependable compound in solid form —packed in 50 lb. cartons—2 litters of pigs to the box—24 easy-to-handle Littlepigs. Easier to ship, handle and store.

FIBREX
(REELS)

FIBREX

(REELS)

The sanitary, bacteria-free joint packing. Easier to use than jute and costs about half as much. Insures sterile mains and tight joints.

HYDRO-TITE

HYDRAULIC DEVELOPMENT CORPORATION

TC
TENNESSEE CORPORATION

The Superior
COAGULANT

Ferri-Floc gives smoother, more efficient and trouble free operation. Whatever your particular water treatment problem may be, you can depend on Ferri-Floc doing a superior job and doing it efficiently and economically—Ferri-Floc is a free flowing granular salt which can be fed with few modifications through any standard dry feed equipment. It is only mildly hygroscopic, thereby permitting easy handling as well as storage in closed hoppers over long periods of time.

With The Plus Factors

Excellent Taste and Odor Control · Coagulation Over Wide pH Range
Rapid Floc Formation · Color Removal · Bacteria Removal
Turbidity Removal · Manganese and Silica removal
Ease of Operation · Economical · Increased Filter Runs

WATER TREATMENT

Efficient coagulation of surface or well water. Effective in lime soda-ash softening. Adaptable to treatment of all industrial applications.

SEWAGE TREATMENT

Ferri-Floc coagulates wastes over wide pH ranges — It provides efficient operation regardless of rapid variations of raw sewage — Is effective for conditioning sludge prior to vacuum filtration or drying on sand beds.

Liquid
SULFUR DIOXIDE
HIGHEST QUALITY
SO_2
Available in:
Cylinders, Ton Drums, Tank Trucks and Tank Cars

SULFUR DIOXIDE is effectively used for dechlorination in water treatment and to remove objectionable odors remaining after purification.

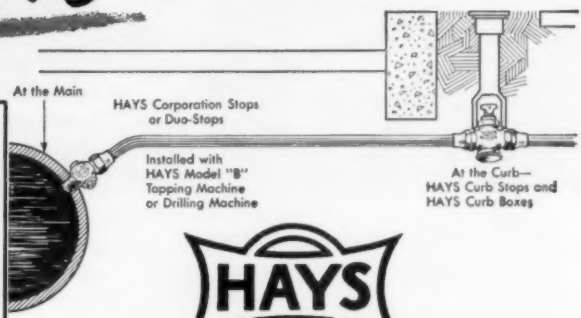
COPPER SULFATE
Available in 100 pound bags.

COPPER SULFATE will control about 90% of the microorganisms normally encountered in water treatment more economically than any other chemical.

TENNESSEE TC CORPORATION
617-29 Grant Building, Atlanta, Georgia

FREE BOOKLET
Let us send you without charge, a 38-page booklet that deals specifically with all phases of ... Just write us a postal card.

For Trouble-Free Service at *Both* ENDS OF THE LINE


At the Main
HAYS Corporation Stops or Duo-Stops
Installed with HAYS Model "B" Tapping Machine or Drilling Machine
At the Curb— HAYS Curb Stops and HAYS Curb Boxes

CORPORATION STOP

ROUNDWAY CURB STOP

DUO-STOP, CORPORATION STOP and SADDLE COMBINED

MODEL "B" TAPPING MACHINE

HAYS

WATER SERVICE PRODUCTS

For underground installations, only the *highest quality* should be considered . . . that's why Water Departments all over the country have been using HAYS Water Service Products for over 80 years.

HAYS makes a complete line of Corporation and Curb Stops conforming to all A.W.W.A. Standards.

Have you investigated the advantages of the HAYS DUO-STOP, (a combined Corporation Stop and Saddle) for safe and easy installation on small service lines?

The HAYS Model B Tapping Machine, with aluminum alloy body, is ⅓ lighter, easier to carry, easier and faster to operate, gives more working room . . . really designed for "the man in the ditch."

Write for literature or ask "The Man from Hays."

Join the A. W. W. A. HAYS is one of the eleven Charter Members of the Manufacturers Section of the American Water Works Association.

HAYS

WATER WORKS PRODUCTS

HAYS MANUFACTURING CO.

ERIE, PA.

BIG... in size *and* quality

This 42" American Bell and Spigot Joint pipe was laid for a water supply line in Texas.

When 42" American Cast Iron Pipe goes into the trench, you can be sure somebody has been thinking. Thinking big.

Big American Cast Iron Pipe means somebody has been thinking of future, as well as present, needs . . not only in terms of future flow capacity requirements, but also in terms of long, economical service. Thinking also in terms of quality, because centrifugally cast American Pipe has an earned reputation for constant high quality.

If your project is important enough to deserve the best, call the experienced American Cast Iron Pipe Company representative near you. It's the first big step to greater economy over a longer service period.

Quality cast iron pipe and fittings are manufactured by the American Cast Iron Pipe Company in 2" through 48" diameters. A wide variety of joints for every purpose is available.

SALES OFFICES

New York City / Chicago
Kansas City / Minneapolis
Dallas / Houston / Orlando
Los Angeles / San Francisco
Pittsburgh / Cleveland
Seattle / Denver

AMERICAN
CAST IRON PIPE CO.
BIRMINGHAM 2, ALABAMA

Which uses the most water?

Filling Station — or Church Building?

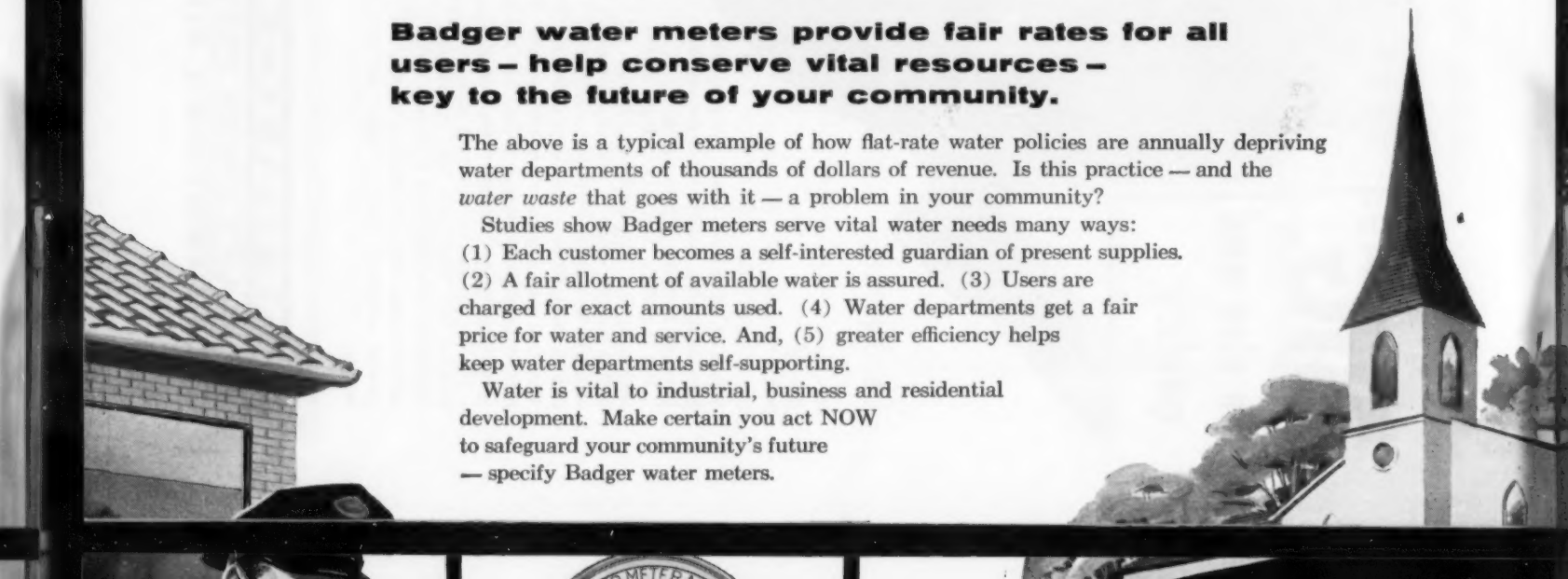
ANSWER: Before one Midwestern community installed water meters, gas stations were billed a flat rate of $12 per year; so were the churches. Last year, the average bill for all filling stations was $48, while in only one case did a church use more water than the minimum charge of $7.20.

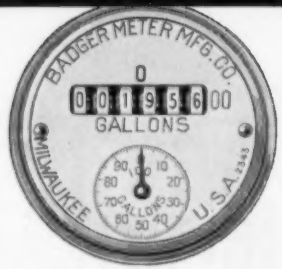
Badger water meters provide fair rates for all users – help conserve vital resources – key to the future of your community.

The above is a typical example of how flat-rate water policies are annually depriving water departments of thousands of dollars of revenue. Is this practice — and the *water waste* that goes with it — a problem in your community?

Studies show Badger meters serve vital water needs many ways: (1) Each customer becomes a self-interested guardian of present supplies. (2) A fair allotment of available water is assured. (3) Users are charged for exact amounts used. (4) Water departments get a fair price for water and service. And, (5) greater efficiency helps keep water departments self-supporting.

Water is vital to industrial, business and residential development. Make certain you act NOW to safeguard your community's future — specify Badger water meters.





Sensitive registering key to maximum revenue per installation

One of the greatest "business machines" your community can own. Badger water meters are always on duty. Dial accurately registers all flow from the smallest stream to maximum meter capacity. Service records also prove the dependability of Badger meters . . . show why waterworks men agree, "It pays to install Badger meters."

For complete details on how Badger meters can help your community save water, work and money, write us.

Badger Water Meters

BADGER METER MFG. CO. • MILWAUKEE 45, WISCONSIN

Water is Vital

"Badger Meters have conserved it for 50 years"

TRINITY VALLEY

for all CAST IRON WATER WORKS FITTINGS

Available On Order

AWWA Standard Bell Spigot Watermain Fittings—24 through 36 inch.

Ring Tite Fitting 3" thru 12"

Available Immediately From Stock

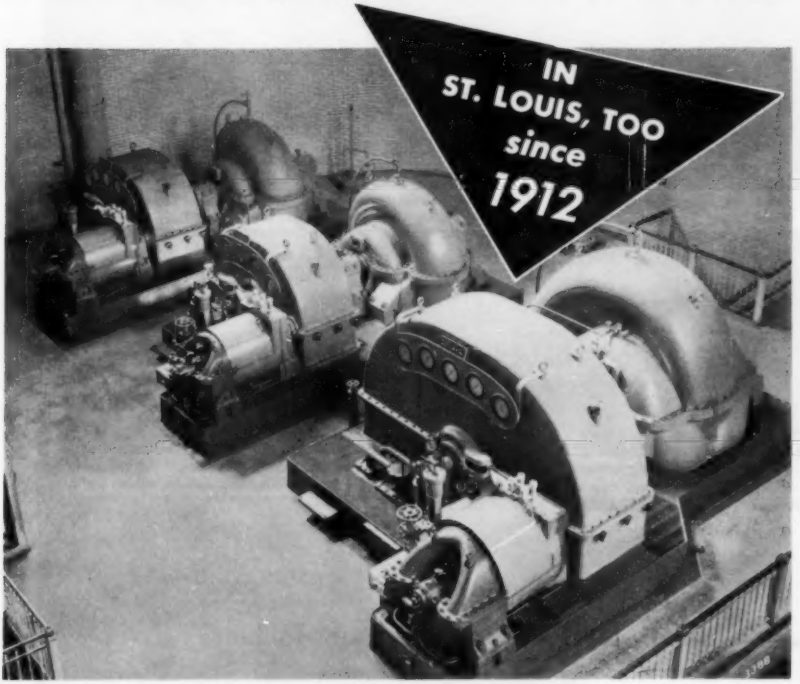
AWWA Approved Short Body and Mechanical Joint Watermain Fittings—2 through 12 inch.

AWWA Standard Bell Spigot Watermain Fittings—2 through 24 inch.

TRINITY VALLEY IRON AND STEEL CO.

Phone PE 7-3141 Fort Worth, Texas P. O. Box 664

DE LAVAL pumps America's water . . .



The three De Laval turbine-driven centrifugal pumps (shown above) have given dependable service in the Howard Bend Station of the St. Louis, Mo. water works system for more than a quarter of a century. The two smaller units have a capacity of 60 mgd and the larger one of 120 mgd, all designed to deliver against 40 ft. head.

In the St. Louis Chain of Rocks Station, De Laval pumps have an even longer service record. Two 40 mgd units were installed in 1912 and a 100 mgd unit in 1918. Two of these three pumps are still on the line. The third has been altered and is still in constant service.

For St. Louis' expanding needs, De Laval is now building ten more centrifugal pumps with a total capacity of 450 million gallons per day.

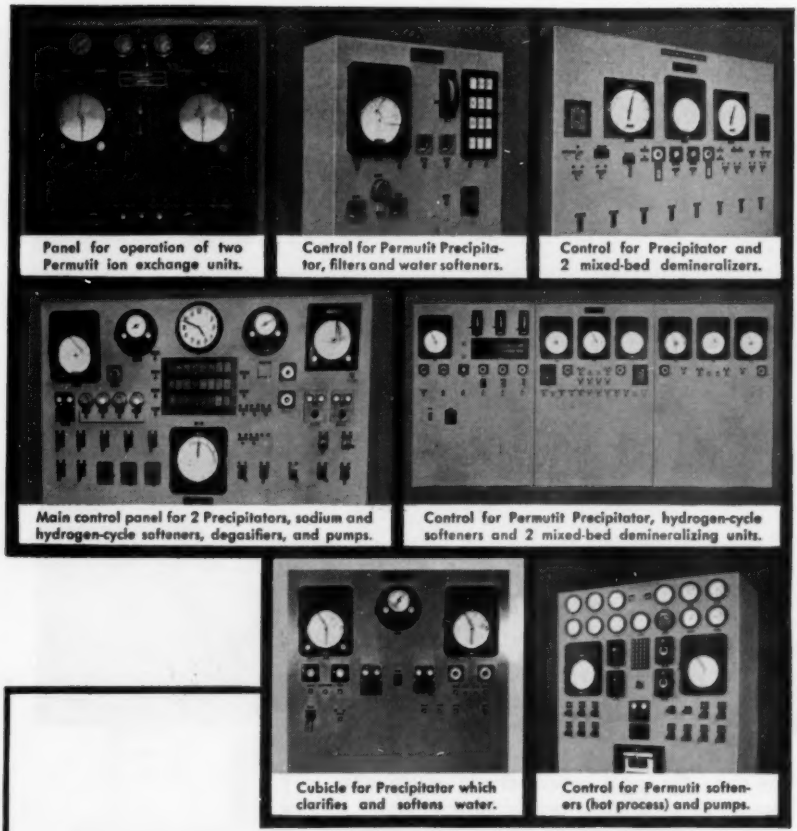
Write for your copy of new De Laval Bulletin 1004

DE LAVAL *Centrifugal Pumps*

DE LAVAL STEAM TURBINE COMPANY

822 Nottingham Way, Trenton 2, New Jersey

DL386A

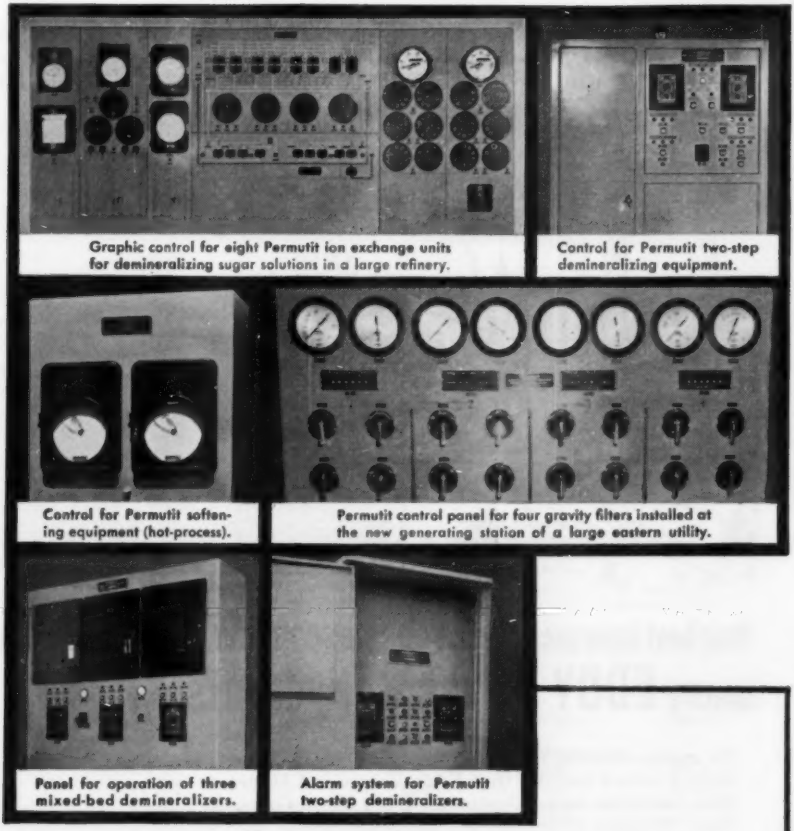

Panel for operation of two Permutit ion exchange units.
Control for Permutit Precipitator, filters and water softeners.
Control for Precipitator and 2 mixed-bed demineralizers.
Main control panel for 2 Precipitators, sodium and hydrogen-cycle softeners, degasifiers, and pumps.
Control for Permutit Precipitator, hydrogen-cycle softeners and 2 mixed-bed demineralizing units.
Cubicle for Precipitator which clarifies and softens water.
Control for Permutit softeners (hot process) and pumps.

Why we make

Life might be simpler if we "farmed out" our control cubicles and instrument panels . . . but we like to build *every* major component of a PERMUTIT water-conditioning or ion exchange system . . . so that we know it will do its specific job properly.

That's why these panels . . . and the hundreds of others in power plants, chemical process plants, manufacturing plants and municipal water works . . . are designed by Permutit engineers and assembled, wired and piped in Permutit factories.

That's why we design and build our own special parts such as multiport valves, strainer systems and



Graphic control for eight Permutit ion exchange units for demineralizing sugar solutions in a large refinery.

Control for Permutit two-step demineralizing equipment.

Control for Permutit softening equipment (hot-process).

Permutit control panel for four gravity filters installed at the new generating station of a large eastern utility.

Panel for operation of three mixed-bed demineralizers.

Alarm system for Permutit two-step demineralizers.

our own panels:

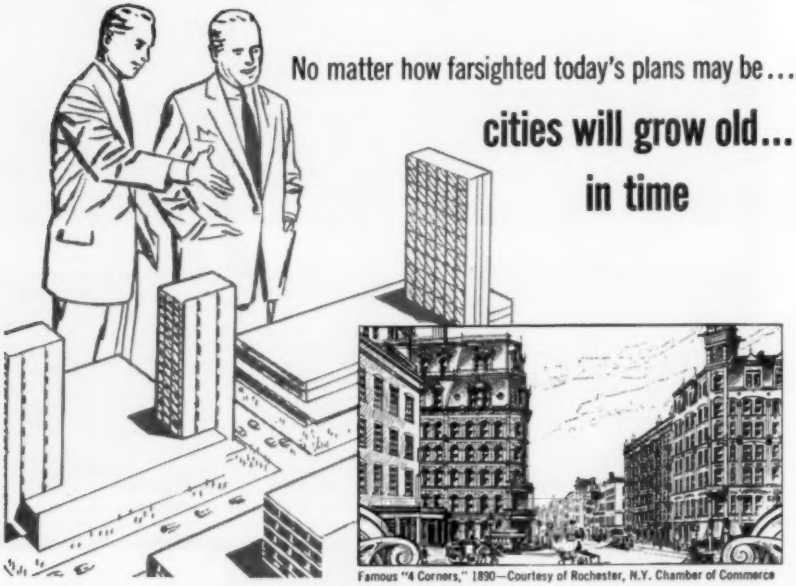
chemical feeders. That's why we make our own ion exchange resins.

As a result, we talk in terms of over-all results. And you get *complete* service from *one* source.

For further information, write to: The Permutit Company, Dept. JA-6, 330 West 42nd St., New York 36, New York.

WATER CONDITIONING • ION EXCHANGE

PERMUTIT®



No matter how farsighted today's plans may be...

cities will grow old... in time

Famous "4 Corners," 1890—Courtesy of Rochester, N.Y. Chamber of Commerce

Your best insurance against obsolescence of your water system... specify EDDY Valves and Hydrants *throughout*

No matter how far into the future your city planning is projected, Eddy's record testifies that Eddy Valves and Hydrants are your best long term investment. Eddy Valve Company's more than 100 years of dependable operation means that, today, you can get replacement parts for any Eddy Valve or Hydrant ever installed. And our ability to continue to do so is your assurance against future obsolescence of your valves and hydrants.

EDDY Bronze-Mounted HYDRANTS
open smoothly *with* the pressure and close without water hammer. One man can easily remove all operating mechanism for inspection and repair. Stem held in place below hydrant valve means that there is no water loss due to a bent stem.

EDDY Bronze-Mounted GATE VALVES
offer simplicity of design, trouble-free operation and enduring service. Each is truly a finished product of workmanship. These factors, added to personal experience, tell why progressive water works men have relied on Eddy for generations.

Eddy Hydrants and Valves are available with hub, flange or mechanical joint connections to fit any existing or planned installation.

EDDY VALVE COMPANY
A Subsidiary of James B. Clow & Sons
WATERFORD, NEW YORK

PLUMBERS — CONTRACTORS — WATER AND SEWAGE WORKS OFFICIALS

"Spring Load" Tools Save You Time and Money

Thousands of plumbers, and contractors, water and sewage department officials, public works department heads and others specify "Spring Load" because they know these tools do the job quicker and with less maintenance. To save time is to save money . . . and you can do it with Spring Load cutters, tenon tools and vises. The right tool for every job is a good investment.

MODEL B TENON TOOL

4" to 8" pipe . . . $195.00 **10" to 20" pipe . . . $315.00**

Recommended by leading asbestos-cement pipe manufacturers, the Model B is the only tool which will make all the cuts and profiles necessary for modern asbestos-cement pipe installations. Saves engineering time by eliminating the need for figuring and specifying short lengths.

- Ring-Tite Couplings
- Fluid-Tite Couplings
- Simplex Couplings
- Roto-Split Flanges
- Poured Flange Assembly
- Tapered Couplings
- Making Closures and End Facing

Completely automatic feed and quick release make the Model B the fastest tenoning tool developed to date. Simply change the cam plate to adapt the tool for cutting any type profile.

TENON TOOL ALSO AVAILABLE IN A STANDARD MODEL FOR SIMPLEX COUPLINGS ONLY — 4" to 8" pipe $90.00 10" to 20" pipe $172.00

CAST IRON AND STEEL PIPE CUTTERS

Model 6 cuts Cast Iron, Duriron, Vitreous Clay Water pipe and Cement Sewer Tile — 2" to 6" pipe . . . $42.50

Model 12 cuts Cast Iron, Duriron, Vitreous Clay Cement Sewer Tile and Steel (with simple changeover to steel wheels) — 4" to 12" cast iron pipe, etc. $84.75

For 4" to 12" for steel pipe only $89.95

Both of these Spring Load Pipe Cutters are heavy duty, precision-built steel-cast cutters designed to exert equal pressure all around the pipe. Cuts are clean and straight, without ears, depressions or splits. Simple and easy to use, the cutters are as practical in the field as in the shop or on the stock pile. Cuts pipe many times faster than ordinary tools and methods.

ASBESTOS-CEMENT PIPE CUTTER — 2" to 8" pipe . . $75.00

You get easy, fast and clean cutting on any asbestos-cement pipe with this on-the-job tool. Practical in the field, at the shop and on the stock pile. Field proven, this tool reduces cutting time 50%. Lightweight—easy to use—no pipe spoilage. Extensions available to increase capacity to 24" pipe.

GRAVITY GRIP VISES

No. V-6 — for 2" to 6" cast iron and steel pipe $24.75

No. V-12 — for 6" to 12" cast iron or steel pipe 44.75

No. V-20 — for 4" to 20" asbestos-cement and clay pipe . . . 44.75

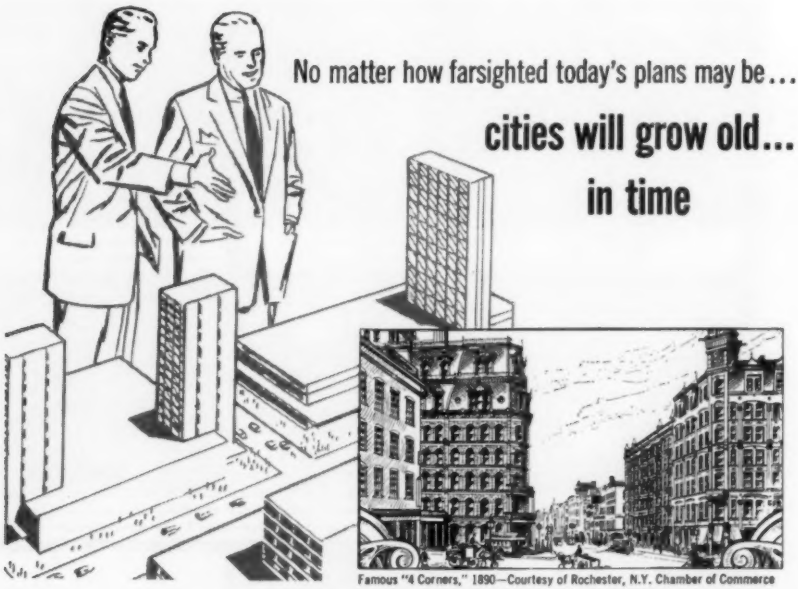
The quickest set-up for holding pipe ever devised. Especially designed for use with Spring Load Cutters and Tenon Tools, the Gravity Grip Vise firmly holds the pipe at a convenient working height and angle.

Send for descriptive literature and price list.
All Spring Load tools are unconditionally guaranteed against faulty workmanship or faulty materials.

SPRING LOAD

MANUFACTURING CORPORATION

3610 First Avenue South Seattle 4, Washington



No matter how farsighted today's plans may be...

cities will grow old... in time

Famous "4 Corners," 1890—Courtesy of Rochester, N.Y. Chamber of Commerce

Your best insurance against obsolescence of your water system... specify EDDY Valves and Hydrants *throughout*

No matter how far into the future your city planning is projected, Eddy's record testifies that Eddy Valves and Hydrants are your best long term investment. Eddy Valve Company's more than 100 years of dependable operation means that, today, you can get replacement parts for any Eddy Valve or Hydrant ever installed. And our ability to continue to do so is your assurance against future obsolescence of your valves and hydrants.

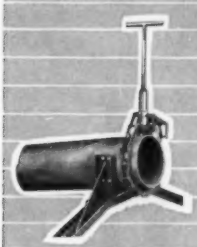
EDDY Bronze-Mounted HYDRANTS
open smoothly *with* the pressure and close without water hammer. One man can easily remove all operating mechanism for inspection and repair. Stem held in place below hydrant valve means that there is no water loss due to a bent stem.

EDDY Bronze-Mounted GATE VALVES
offer simplicity of design, trouble-free operation and enduring service. Each is truly a finished product of workmanship. These factors, added to personal experience, tell why progressive water works men have relied on Eddy for generations.

Eddy Hydrants and Valves are available with hub, flange or mechanical joint connections to fit any existing or planned installation.

EDDY VALVE COMPANY
A Subsidiary of James B. Clow & Sons
WATERFORD, NEW YORK

PLUMBERS — CONTRACTORS — WATER AND SEWAGE WORKS OFFICIALS



"Spring Load" Tools Save You Time and Money

Thousands of plumbers, and contractors, water and sewage department officials, public works department heads and others specify "Spring Load" because they know these tools do the job quicker and with less maintenance. To save time is to save money . . . and you can do it with Spring Load cutters, tenon tools and vises. The right tool for every job is a good investment.

MODEL B TENON TOOL

4" to 8" pipe . . . $195.00 10" to 20" pipe . . . $315.00

Recommended by leading asbestos-cement pipe manufacturers, the Model B is the only tool which will make all the cuts and profiles necessary for modern asbestos-cement pipe installations. Saves engineering time by eliminating the need for figuring and specifying short lengths.

- Ring-Tite Couplings
- Fluid-Tite Couplings
- Simplex Couplings
- Roto-Split Flanges
- Poured Flange Assembly
- Tapered Couplings
- Making Closures and End Facing

Completely automatic feed and quick release make the Model B the fastest tenoning tool developed to date. Simply change the cam plate to adapt the tool for cutting any type profile.

TENON TOOL ALSO AVAILABLE IN A STANDARD MODEL FOR SIMPLEX COUPLINGS ONLY — 4" to 8" pipe $90.00 10" to 20" pipe $172.00

CAST IRON AND STEEL PIPE CUTTERS

Model 6 cuts Cast Iron, Duriron, Vitreous Clay Water pipe and Cement Sewer Tile — 2" to 6" pipe . . . $42.50

Model 12 cuts Cast Iron, Duriron, Vitreous Clay Cement Sewer Tile and Steel (with simple changeover to steel wheels) — 4" to 12" cast iron pipe, etc. $84.75

For 4" to 12" for steel pipe only $89.95

Both of these Spring Load Pipe Cutters are heavy duty, precision-built steel-cast cutters designed to exert equal pressure all around the pipe. Cuts are clean and straight, without ears, depressions or splits. Simple and easy to use, the cutters are as practical in the field as in the shop or on the stock pile. Cuts pipe many times faster than ordinary tools and methods.

ASBESTOS-CEMENT PIPE CUTTER — 2" to 8" pipe . . $75.00

You get easy, fast and clean cutting on any asbestos-cement pipe with this on-the-job tool. Practical in the field, at the shop and on the stock pile. Field proven, this tool reduces cutting time 50%. Lightweight—easy to use—no pipe spoilage. Extensions available to increase capacity to 24" pipe.

GRAVITY GRIP VISES

No. V-6 — for 2" to 6" cast iron and steel pipe $24.75

No. V-12 — for 6" to 12" cast iron or steel pipe 44.75

No. V-20 — for 4" to 20" asbestos-cement and clay pipe . . . 44.75

The quickest set-up for holding pipe ever devised. Especially designed for use with Spring Load Cutters and Tenon Tools, the Gravity Grip Vise firmly holds the pipe at a convenient working height and angle.

Send for descriptive literature and price list.
All Spring Load tools are unconditionally guaranteed against faulty workmanship or faulty materials.

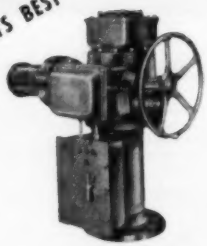
SPRING LOAD

MANUFACTURING CORPORATION

3610 First Avenue South Seattle 4, Washington

VALVE ACTUATION

ENGINEERING AT ITS BEST



Motor Operated Stand with Integral Control Equipment

MOTOR OPERATED VALVE

Power actuation is available as a complete carefully engineered unit. Actuation may be by electric motor, air motor, or air or fluid cylinder type motivation. The power unit is compact and self contained, with sturdy supports which attach to the top of any Ludlow Valve.

Manual operation is provided for all electric and air motor operated valves. Our engineers will be glad to help you lay out a plan based on the many years of Ludlow experience in power actuation systems of all kinds for all purposes.

"NO POSSIBLE DIFFERENCE IN FIRST COST CAN OVERBALANCE THE PERPETUAL ECONOMY OF QUALITY."

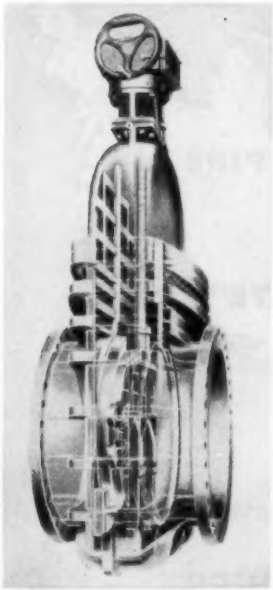
19

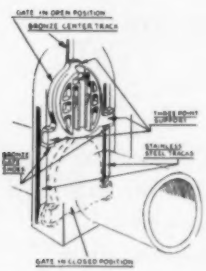
CYLINDER OPERATED VALVE

THE LUDLOW VALVE MFG. CO., INC. TROY, N.Y.

TRADE LUDLOW MARK

GATE VALVES • FIRE HYDRANTS • SQUARE BOTTOM VALVES
CHECK VALVES • TAPPING SLEEVES • AIR RELEASE VALVES





SQUARE BOTTOM VALVES

The Rensselaer Square Bottom Valve may well be called the "work horse" of the valve family. It is built to stand up under the severe conditions found in automatic operation, throttling, differential pressures and the constant opening and closing found in filtration plants and process industries.

A three-point gate support holds the downstream gate away from its seat ring at all points of travel except the final, fully closed position. Any tendency for the downstream gate to tilt and score the face of the seat ring under conditions of high water velocity or throttling service is eliminated.

At all points this valve is built for long life under constant and severe operation.

IN OPENING: the shoes slide up the stainless steel track inclines to the higher level of the tracks, lifting the gate clear of the bronze seat ring.

IN CLOSING: the gate does not come in contact with the bronze seat ring until the closing point is reached. Even when partly open, the gate is held away from the seat, eliminating all wear due to vibration.

Rensselaer Square Bottom Valves are made in sizes from 4 to 48" with any type end connection. By-passes, spur or bevel gearing, and cylinder or motor operation as desired. 20

Rensselaer
VALVE CO. **TROY, NEW YORK**

DIVISION OF
THE LUDLOW VALVE
MANUFACTURING CO., INC.

GATE VALVES • FIRE HYDRANTS • SQUARE BOTTOM VALVES
CHECK VALVES • TAPPING SLEEVES • AIR RELEASE VALVES

Concrete Pressure Pipe is universally accepted for city water systems

as witnessed by its use in all major cities in the United States and Canada

Great supporting strength, high carrying capacity and long life make Concrete Pressure Pipe ideal for city water supply lines, transmission lines, and distribution mains.

Modern manufacturing plants are located so as to make Concrete Pressure Pipe available in all sections of the United States and Canada.

Member companies are equipped to manufacture and furnish concrete pressure pipe in accordance with established national specifications and standards.

Concrete PRESSURE Pipe

WATER FOR GENERATIONS TO COME

AMERICAN CONCRETE PRESSURE PIPE ASSOCIATION
228 North LaSalle Street
Chicago 1, Illinois

Champion Fire Fighters

COMPRESSION TYPE FIRE **HYDRANT**

M H

Above all else, M & H Fire Hydrants are reliable and dependable fire fighting equipment. They deliver when the need arises, if there is water in the mains. Their high flow efficiency is due to an unobstructed, large waterway which has the same diameter its entire length.

Dry top, dry barrel when not in use, eliminates danger of damage by freezing. Operating parts are bronze or bronze bushed. Easy to lubricate.

Manufactured according to A. W. W. A. standard specifications or Underwriters and Factory Mutuals approved; in conventional model, traffic model or flush-type model; sizes 4¼, 4½, 5¼ and 6¼. For complete information, address

M&H VALVE AND FITTINGS COMPANY
Anniston, Alabama

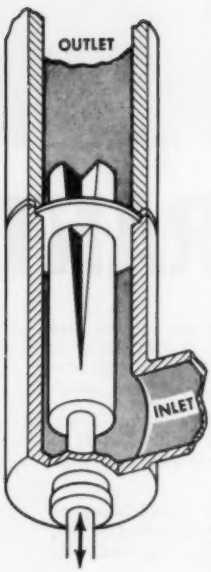
M&H PRODUCTS FOR WATER WORKS • FILTER PLANTS INDUSTRY • SEWAGE DISPOSAL AND FIRE PROTECTION

THE WALLACE & TIERNAN

V-NOTCH

variable-orifice

... a new concept for chlorinator control



The W&T V-notch Variable-Orifice is the heart of a new chlorinator control system. With the system, a constant differential vacuum is maintained across the V-notch Variable-Orifice and the flow of chlorine gas is adjusted by varying the area of the orifice.

The W&T V-notch Variable-Orifice has these features:

- Wide range adjustment of chlorine flow
- Excellent reproducibility of flow by a simple adjustment
- Same % accuracy over entire wide flow range

As can be seen in the diagram, the V-notch Variable-Orifice is formed by a cylindrical plug positioned inside a matched, circular ring. A V-shaped groove is machined along the length of the plug. The groove starts near one end of the plug and gradually enlarges to its maximum width and depth at the other end of the plug. The V-notch Orifice is formed at the intersection of the grooved plug and the matched ring. The orifice area is varied simply and positively by positioning the plug backward or forward inside the fixed ring.

The V-notch Variable-Orifice is just one design feature of the new W&T V-notch line of Chlorinators. Get all the facts about the W&T V-notch chlorinators before you buy chlorination equipment.

WALLACE & TIERNAN INCORPORATED

25 MAIN STREET, BELLEVILLE 9, NEW JERSEY

S-108

Journal

AMERICAN WATER WORKS ASSOCIATION

VOL. 48 • JUNE 1956 • NO. 6

Automatic Operation at the Broadside Filter Plant in Scotland

Eric W. Denholm

A contribution to the Journal by Eric W. Denholm, Engr., Stirlingshire & Falkirk Water Board, Scotland. The paper was presented on Apr. 20, 1956, at a meeting of the Scottish Section of the British Institution of Water Engineers, Glasgow, Scotland, and is printed here by permission of the Institution.

NOTE: *Technical usage and terminology differ from country to country even when, as in the United States and Great Britain, the same language is spoken. In the belief that an exposure to British usage may prove enlightening to American readers, the editors have, with few exceptions, preserved the original diction, appending footnotes wherever the context does not render explanation superfluous. Abbreviations, punctuation, and spelling have, however, been changed to conform to Journal style. In all cases, use of the term "gallons," or abbreviations thereof, should be understood to denote Imperial gallons. To obtain US gallons, multiply the figures given by 1.2.*

THE end of World War II found the Stirlingshire and Falkirk Water Board owning Carron Valley Reservoir, completed in 1939, and lacking the means of distribution and filtration to make use of it. The reservoir has a storage capacity of 4.2 mil gal, a net yield of 11.6 mgd, and a potential future net yield, by catchment area extension, of at least 22 mgd.

By 1948, the physical characteristics of the reservoir water had settled down as shown in Table 1. Troubles from algae, daphnia, and peat disintegration are experienced seasonally.

Contemporaneously with the decision of the board in 1946 to put its own distribution system in order, a very large water-consuming project, sponsored by the oil industry and other interests, decided to settle in the area, and a large dyestuffs factory, already established there, was the subject of proposals for considerable extension.

These industries had nowhere else to turn but to the board for their large-scale requirements, and agreement to afford them the necessary supplies was reached in July 1948.

The first stage of the Broadside Filtration Plant was designed with a capacity of 12.65 mgd, based on a rating of 75 gph per square foot of filtering surface, in twelve filters. It will ultimately, when extended, have a capacity of 21 mgd at the same rating. The plant was officially opened on Oct. 31, 1952.

In Great Britain, where every filter contractor has his own patented plant, it is extremely difficult to get competitive tenders and yet not tie those tendering wholly to one's own requirements. The following procedure was adopted.

In September 1948, a preliminary detailed specification, incorporating a sketch of the board's own proposals, and leaving provision for alternative proposals, was sent out to selected firms. Replies to this preliminary questionnaire were received at the end of November 1948. Three firms were then selected and asked to tender for exactly the same equipment to a layout provided by the board; but the specification at the same time provided latitude to quote for alternatives, incorporating the firm's own patented equipment if desired.

Automatic Control

In many aspects of water works, automatic control is not new, and, in the belief that complete automation was not many years ahead, an attempt was made to make the Broadside plant as fully automatic as was felt to be practicable. The plant is, therefore, believed to be the most fully automatic constructed to that date. There are a number of plants in various parts of the world incorporating automatic filter washing, mainly after manual selection, but, where the filters do not operate with air scour and have no surface flush, such an arrangement is relatively simple. Other plants incorporate provision for automatic chemical proportioning, or automatic filter flow regulation; or again, they have been arranged to shut down, reopen, or vary the rate of flow, automatically. At Broadside, however, all these operations, including the selection of the filters for washing, are carried out automatically, and, in addition, each operation of the plant is interlinked with a comprehensive system of alarm signals.

Plant Layout

The site, covering about 8 acres, is fairly evenly graded from 665.0 to 635.0 O.D.* with a steep bank to the Overton Burn, a small river at 620.0 O.D. The plant is encircled by a 12-ft wide roadway to allow lorries with chemicals to approach full from one direction and leave empty by the other side of the plant. Figure 1 shows how room has been left for extension by the addition of a further sixteen settling tanks and eight filters on the wings of the administration block, without encroaching on any of the roads.

A fountain, incorporating a cherub from the board's crest, in front of the main entrance door, and a rose garden on the slope between the fountain and the access road, serve to provide amenity and enhance the appearance of the plant.

* O.D. or "ordnance datum" refers to height (in feet) above mean sea level. Until the beginning of World War II, the datum level was that of a granite block in the Old Dock at Liverpool. Since then, the datum has been changed to Newlyn, but the new level is not yet universal.

The 40-in. inlet main divides into two 24-in. mains controlled by two 24-in. sluice valves and two 24-in. float-controlled equilibrium valves. The latter items automatically adjust the rate of flow into the plant. The dual entry allows either valve to be isolated for repairs, thus permitting normal filtration to continue.

The inlet channel incorporates a screen to collect any foreign material, including fish, which might affect the operation of the chemical flash mixer. The bars of this screen were specially selected in section, to cause as little head loss as possible and yet allow them to be set closely enough ($\frac{3}{4}$-in. spacing) to turn fish of 10-oz weight and over. A sump is provided below the screen to allow fish to regain relatively still water. The water then passes through a venturi meter and then on to the flash mixer.

TABLE 1

Characteristics of Carron Valley Reservoir Water, 1948

Item	Amount
pH value	6.7–6.9
Color—*units**	40–60
Total solids	
Mineral matter—*ppm*	25
Organic matter—*ppm*	25
Free CO_2—*ppm*	3–4
Hardness	
Temporary—*ppm as* $CaCO_3$	8.6–14.3
Permanent—*ppm as* $CaCO_3$	14.3–21.5

* Measured against Hazen platinic chloride standard.

Chemicals for coagulation are introduced into the inlet channel, and the water then enters the flash-mixer chamber through the bottom against a steel spreader plate. Mixing is achieved by drawing water at a rate of 350 gpm from the raw-water channel by centrifugal pump and returning it vertically downwards into the mixing chamber on the upper side of the spreader plate, thus producing considerable turbulence and effective mixing. There is, therefore, no mechanical equipment, requiring maintenance, operating in the raw water. From the flash mixer onwards, until the water is returned into the filtered-water channel, its procedure on both sides of the plant is identical.

The triple channels between each double row of settling tanks have the raw-water channel in the center and the settled-water channels on the outside. The bottoms of the 29-ft square settling tanks are in the shape of inverted pyramids, with 60-deg slopes, and the chemically charged raw water is introduced at the bottoms of the pyramids, thus producing the necessary rotary action for flocculation. The water then rises vertically through a blanket of suspended sludge in which the particles are built up into larger and denser particles.

Settled or clarified water is drawn off evenly into a series of decanting troughs which eliminate short-circuiting and formation of dead patches. The level of the blanket tends to rise, and is controlled by a submerged weir pocket which permits a continuous discharge of sludge into the sludge drains and thence to the sludge lagoons. Heavy sludge can be removed periodically from the hoppers under hydrostatic head, and here again the tanks operate without any mechanical agitating or desludging equipment. These tanks have been very well tried, having been first introduced in India as long ago as 1933.

The twelve filter units are each of 570 sq ft of sand area with a capacity of fully 1.05 mgd (an actual rate of 77 gph per square foot). The water enters each filter through a 12-in. inlet

penstock set in the face of the settled-water channel wall and leaves the filters through a 12-in. automatic flow controller, finally entering the filtered-water channel under the pipe gallery, where it rejoins the water from the other side of the plant. Sand storage platforms are provided on each side of the administration building for use if it should become necessary to remove sand from any of the filters.

The handling of chemicals is not such a problem at Broadside as it would be in a softening plant, and it was accordingly decided to handle these mechanically rather than automatically. Automatic handling is more easily arranged with dry-feed chemicals.

Lorries carrying kibbled alumina * and soda ash enter the chemical house and discharge immediately over hoppers suspended from the underside of

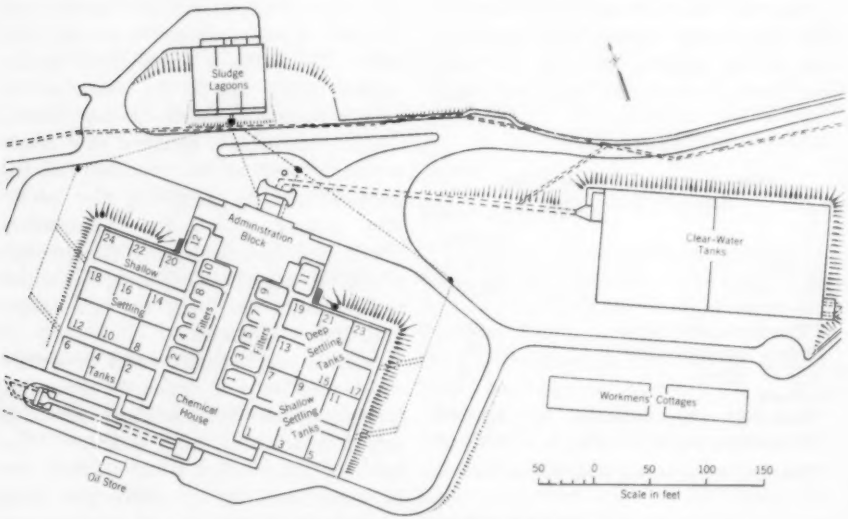


Fig. 1. Layout of Broadside Filtration Plant

The site, which covers about 8 acres, is fairly evenly graded, with a steep bank sloping down to the Overton Burn, a small stream diverted to the north of the sludge lagoons.

Lime and chlorine entry is at, and beyond, the junction of the main filtered-water channel with the channels from the filters on the side wings. Here also, as on the raw-water channels, grooves are provided in which to insert dividing boards to isolate sections of the plant for repairs. The filtered water is finally metered before leaving the administration building.

the floor. In the basement, the hoppers discharge through mechanical gates, as required, into a rail wagon which is pushed forward over a weighing machine and lifted through a hatch in the floor above by electric overhead travelling crane, to discharge into the appropriate solution tank. The crane skip is self-emptying. Lorries carry-

* Kibbled alumina is alumina broken into pieces which would pass a riddle of about 2-in. square mesh.

ing lime discharge similarly into the lime basement through hopper doors in the floor, and the lime is again carried in a rail wagon over a weighing machine and lifted into the slaker by the overhead travelling crane. The lime slurry is pumped through the pipe gallery to the milk-of-lime tanks in the administration basement. Chlorine drums are handled directly off the lorry by overhead gantry.

The clear-water tank is in two compartments of 1-mil gal capacity each. From the outlet of this storage reservoir a 36-in. main carries the water into supply.

Filtered water is pumped from the filtered-water channel into the wash water tank in the roof of the administration building. Pumps start and stop automatically by means of the usual float switches.

Waste water and the sludge bleeds from the settling tanks flow by gravity to the sludge lagoons. From there, after settlement, the supernatant water is picked up by floating-arm draw-offs, and is pumped back to the raw-water inlet channel between the venturi meter and the flash mixer. Starting and stopping of the supernatant return pumps is by means of a "no-float" switchgear.*

The sludge lagoons have floors sloping at 5 deg for five-sixths of their length, finishing in pyramidal ends. Sludge can be disposed of directly to the Overton Burn, drawn off into tank wagons, or pumped to drying beds.

The plant is provided with an 18-in. diameter raw-water bypass main which joins a 27-in. diameter filtered-water bypass main round the clear-water tank.

All pumps, motors, and similar running gear are in duplicate; and (for simplicity in storekeeping and repairs) all of the pumps are identical units, even though some may not be operating at maximum efficiency.

Hydraulic Design

Limiting velocities were specified in detail and very little alteration had to be made as the design proceeded. Some of the velocities call for comment.

Between the flash mixer and the bottom of the sludge blankets in the settling tanks, velocities are critical and for this section the velocity was limited to 2 fps at 11 mgd and 2.5 fps at ultimate maximum flow. The final velocity in the square section of the settling tanks was specified not to exceed an ultimate figure of 0.83 ipm. These velocities may be conservative, but they were fixed advisedly, for the plant is dealing with a water containing very little particulate suspended matter and only colloidal organic matter and color.

The downward velocity in the filters is at the rather conservative rate of 2.5 ipm. With some waters it has been possible to run filters efficiently for very long periods at flow rates as much as 50 per cent greater than that figure. There must come a time, as the rate increases, when it will be difficult to determine whether results are being obtained by filtration or by chlorine sterilization. The filter outlet modules are each capable of passing 2 mgd, a circumstance which leaves scope for research into the effect of

* A Lectralevel unit, manufactured by Londex Ltd., London, is used. This type of control, commonly known as a "no float" unit, consists of two electrodes of different lengths, penetrating into the water level chamber from the top. The lengths are adjustable to give the required levels for stopping or starting the pumps. The electrodes are connected to an electric relay unit so that when the water rises to make contact with the higher of the two electrodes it completes the electric circuit and brings the relay into operation, closing the pilot coil circuit of the automatic starter on the pumps, thus starting the motor. The relay is designed to hold this condition until the water level falls below the level of the longer electrode, at which point the circuit is broken and the pumps stopped. The relay is operated on low-voltage alternating current through a transformer.

different rates of flow on sand, wash water, and other substances.

The water level in the inlet channel between the float valves and the fish screen at 11 mgd is 659.42 O.D. The top water level in the clear-water tank is 645.80 O.D., a total decline through the plant of 13.62 ft.

Inlet and Outlet Meters

A venturi flume was considered, in order to give turbulence in a "hydraulic jump," for chemical mixing; but, with the decision to install the chemical flash mixer, a square-section venturi tube was constructed in concrete. A metering range of 20 to 1 had been specified, but this is beyond the range of an electrical transmitter, owing to the fact that the number of wires covered by the feeler arm on the wound resistance becomes very small at the lower end of the range.

The meter manufacturers then developed an ingenious arrangement using a short 4-in. venturi tube in parallel with the main meter, to magnify the differential head across the main meter. There are now two electrical transmitters covering the full range. The operation is entirely automatic, switching over from one transmitter to the other at a predetermined flow, and switching back again when the flow increases. A similar arrangement was adopted for the venturi meter on the filtered-water channel.

Settling Tanks

Because of rock levels, brought to light by the exploratory borings, it was decided not to use the normal single-hopper settling tanks over three-quarters of the site. Sixteen tanks were accordingly subdivided internally into four hoppers each, adding rather more to the cost of inlet and desludging pipes, but showing a compensatory saving of 13 ft in excavation and cutting out the necessary support from the rock surface. A section through the shallow settling tanks and sludge gallery is shown in Fig. 2. Both types of tank have come fully up to expectations in their operation over the past 3 years.

It was anticipated during construction that there might be some disturbance of the sludge blanket (which has its surface normally 3 ft below top water level) during periods of high wind, but this effect has been suffered only on one occasion, disturbance of the blankets being confined to the shallow Tank No. 2 and to the deep tanks No. 21 and 23 (*see* Fig. 1). Although the board has no recorded figures of its own, wind storms, with gusts of 70 mph and greater, have been reported on a number of occasions. It may be that the freedom from trouble is merely fortuitous and is due to the relative positions of the settling tanks and the administration and chemical buildings; but so far no research has been done on this point.

Corrosion

At the board's five pressure plants * considerable maintenance has been necessitated as a result of corrosion caused by the acid nature of the filtrate. Even the cast-iron strainers in the filter bottoms have had a life of only 25–30 years. The specification for Broadside accordingly called for noncorrodible materials throughout, and this has led to the use of some

* The pressure plants referred to are pressure filters, that is, rapid filters enclosed in steel shells and designed to be placed in a main where the head cannot be broken. In Scotland, this type of rapid filter has been used for many years, and the filtered water discharged thereafter into a clear-water tank. The author believes the American practice to be preferable, for if the head is to be broken a rapid-gravity plant is the correct type.

materials not usually met with in similar circumstances.

The decanting troughs over the settling tanks were fabricated of asbestos cement, painted with bitumen. After 3 years' use they are in as good condition as when installed. They have notches, 1¾-in. wide by 1-in. deep in the top edge, spaced at 12 in. from center to center. The usual steel decanting trough requires considerably more upkeep; its edges are likely to deteriorate in a very short period, as the water with which they are in contact has a pH value of about 5.6.

The lateral pipes in the filter floors are 4-in. diameter unglazed blue Staffordshire ware; the nozzles are of arsenical aluminum brass.

Chlorine solution is carried through the plant in pyrex glass tubing. Spun-iron pipes are concrete lined or in two cases vitreous enamelled internally. All mild steel in water is heavily galvanized.

Filter Design

Figure 3 shows a section through the filter and pipe gallery. In the filter floor, the lateral pipes are imbedded in concrete at 7.2 in. from center to center, and drain into a central channel serving the dual purpose of collecting the filtered water and introducing the upwash. These lateral pipes carry nozzle plates into which are fitted special filter nozzles at 7 in. from center to center, the floor being finished flush with the tops of the nozzle-plate bushes, thus presenting a flat surface from which the nozzles can be removed for inspection at any time.

Air is distributed through 5-in. cast-iron header pipes with heavy-gage copper connections to each individual lateral. The nozzles not only insure uniform collection of the filtered water, but also provide separate orifices for the independent control and uniform distribution of the air and water when washing the filter bed.

A survey was made of various types of filter floors and, although wholly satisfied with the general design of the floor selected, the author felt that none of the filter floors in normal use could be relied upon to provide a satisfactory and speedy air and water distribution indefinitely over an area larger than 600–700 sq ft. A filter of similar size which had been installed with the same type of floor 14 years previously was examined, and, although the sand bed had not been disturbed in the intervening period, both air and water came up uniformly over the bed in a matter of seconds. That has also been the experience at Broadside, and there appears to be no reason why any deterioration in the performance of the floor as a whole should ever occur.

The filtering medium consists of: 4 in. of ½–¼-in. pebbles; 4 in. of ¼–⅛-in. gravel; 4 in. of 10–20 sand; and 30 in. of 20–30 sand.*

A 26-hp motor drives an air blower to provide 1.33 cfm of free air per square foot of filter area at an initial pressure of about 5 psi, which soon falls to a running pressure of about 3.5 psi. There is no compressed-air receiver. The air blowers are in a separate silenced room in the administration basement; and to prevent exhaustion of the air in the room a 10-in. diameter air duct was taken out to the open air at one of the sand platforms.

Sufficient filtered water is stored in the roof of the administration building to afford three 8-min washes. The water is supplied to the filters through

* 10–20 and 20–30 are sand sizes. For instance, in the first case the sand will pass a sieve with ten meshes to the inch and be retained on a sieve with twenty meshes to the inch.

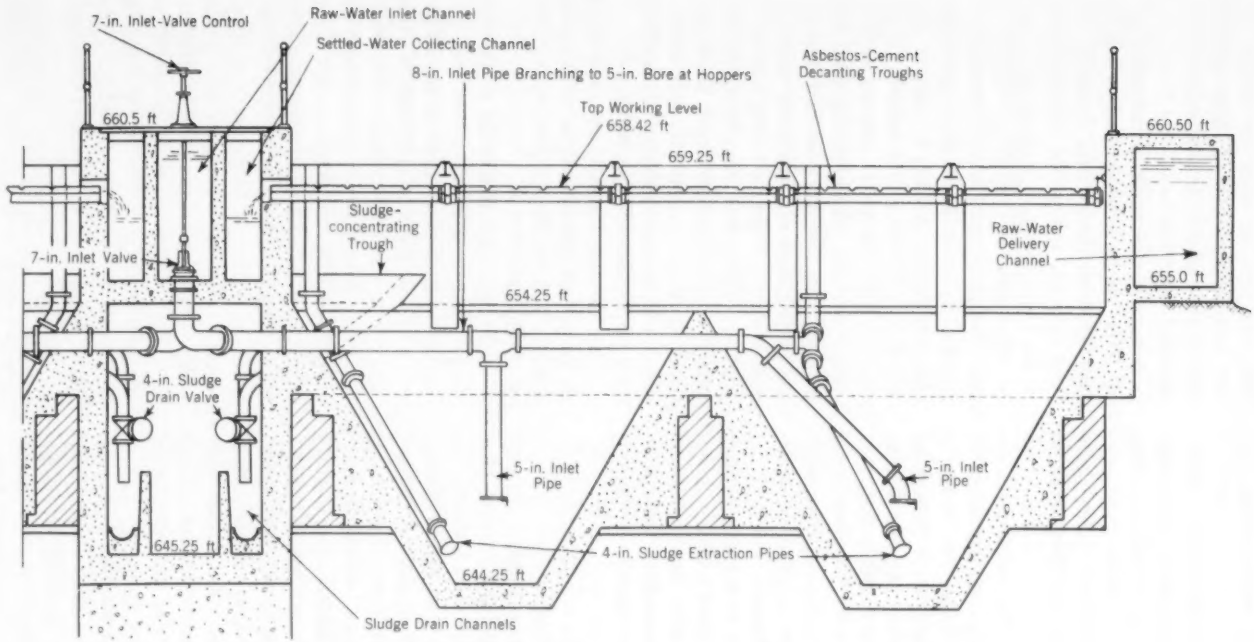


Fig. 2. Section Through Shallow Settling Tanks and Sludge Gallery

There are twelve setting tanks of the inverted pyramid type on each side of the plant, each 29 ft square at water surface and allowing a maximum upward velocity of ¾ ipm. Coagulated water enters the settling tanks through pipes at the base of the pyramids and rises to flow out over the edges of the decanting troughs. In this process a blanket composed of coagulant and suspended matter from the water is built up, and the continuing process of building up the blanket during the passage of the water materially reduces the load on the filters themselves.

a 15-in. diameter main, and the quantity of wash water is set by adjustable stops on the control valves at each filter to a rate of 6 gpm per square foot of filter area. The head from the top water level of the wash water tank to the sand surface is 36 ft.

The wash water from the sand bed is discharged over a sill 4½ in. high at the end of the bed into a washout bay. The sand is not expanded. The wash water, on breaking through the sand, and then flowing horizontally across the sand bed, is continually increasing in velocity and therefore carries with it the dirt which has been removed from the bed. At the end of the wash, such dirty water as remains above the sand bed is removed by the surface flush. This is achieved by admitting the incoming settled water and deflecting it horizontally across the full width of the filter, thus pushing ahead of it any residual dirty water into the washout bay. The depth of water normally overlying the sand is 8 ft, and filters are backwashed when the head loss reaches 6 ft.

Any loss of sand has been entirely confined to the smallest particles which are present in all filter sands, and such loss is normal. During 3 years of operation there has been no need to replenish sand in any of the filters.

The washing arrangements at Broadside appear to be a fundamental improvement over any system using troughs spanning the sand bed; in the latter the wash water, as it rises, tends to leave some dirt behind whether or not air has been used for scrubbing. A siphon drawoff is the only method known to the author for defeating this weakness in design.

The author has not been aware of any filtration plant operated with air and low-velocity wash in which trouble has been experienced from mudballing. This malady is apparently confined to systems using a high-velocity wash in which the sand is expanded and, further, using that high-velocity wash without first breaking up the surface of the sand with air or by some other equally efficient means. Where sand is expanded by the wash water and resettles, it is known that the heavier particles return to the lower levels and the filter grading is not disturbed. When the sand settles, any lumps of gelatinous matter, of higher density than the sand, which have not been displaced over the wash water troughs, sink to a lower level than that originally occupied. With each wash the lumps sink lower and lower down the sand bed, until they ultimately choke the filter floor.

Automatic Chemical Regulation

Solution feed was specified for all chemicals, mainly as a precaution, which may or may not have been justified. With dry feeders, since most of the chemicals used are hygroscopic, and even deliquescent, difficulties can arise through condensation and consequent dampness; after all, the chemicals are ultimately to be dissolved in the water. Troubles from condensation have been minimized by thermostatically controlled heating from an oil-fired boiler, but despite this it was felt that solution feed was to be preferred.

The raw water, taken from adequate storage, does not vary hourly in condition, as with many river supplies, such variation as there is being seasonal. For that reason the question of automatic control of chemical dosage, though given consideration, was not pursued. It is true to say, however, that chemical dosage does not necessarily vary directly with change in the

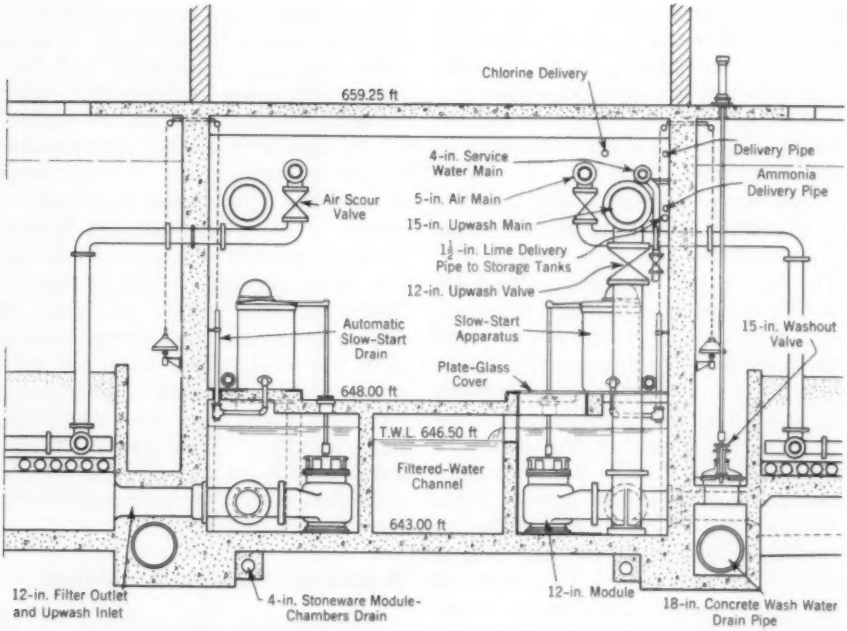


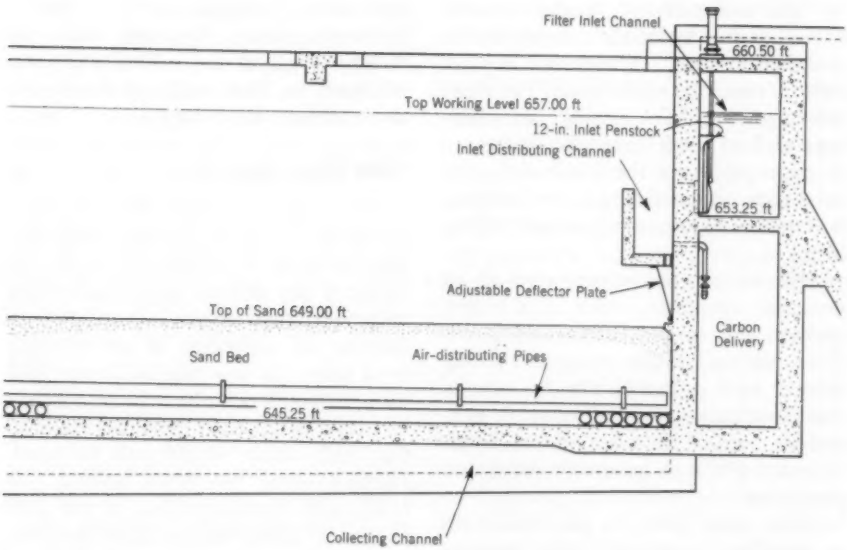
Fig. 3. Section Through

condition of the raw water, and indeed it is often suspected that in practice they bear little relation to one another, the only true test being the resultant floc.

The variable in normal operation, which can be used to initiate automatic control, is the quantity of chemical solution which, once the dose is preset, must vary with the rate of flow of water through the plant. At Broadside only a daily check on dosage need be made, although it is conceded that where the condition of the raw water varies from hour to hour, 24-hr control throughout the day would be necessary.

The original intention was to use a centrifugal balancer working in conjunction with the inlet venturi meter and designed to maintain the speed of a lineshaft strictly proportional to the flow through the inlet meter by means of an infinitely variable gearbox under the control of a hydraulic relay.

There were design difficulties, not insurmountable, arising from the fact that the differential head varies as the square of the flow, while a variation in direct proportion to the flow was required. Also, the provision of the bypass meter on the inlet venturi meter raised further complications. On reconsideration, it was decided to utilize the differentials created by the metering system to operate an electronic proportional-speed control through a variable-speed motor. This is the only electronic control throughout the whole plant, apart from well tested proprietary metering equipment.



Filter and Pipe Gallery

The electrical transmitter on the inlet meter was fitted with a 500-ohm slide-wire resistance giving a linear scale with a high degree of approximation over the full flow range of 20 to 1. The electronic control unit * adjusts the speed of a d-c motor so as to vary linearly in accordance with the slide-wire resistance and hence in accordance with the flow. The electronic unit comprises a transformer and thyratron valve † rectifiers to provide the d-c supply to the motor. The armature voltage is used as a measure of the motor speed, and is compared with a reference voltage derived from the 500-ohm slide wire.

The d-c motor, in turn, drives a lineshaft which varies in speed in proportion to the flow and which drives a battery of variable-stroke metering pumps, on which the dose has been preset to supply the various chemicals.

Hydraulic Remote Control

The valves controlling the inlet, upwash, washout, and air flow on each filter are equipped with double-acting slave cylinders and are operated hydraulically by high-pressure oil.

Each filter valve is connected, when required, to the central oil-pressure system through a hydraulic relay which is energized by the solenoid-operated filter bed selector valve at the filter.) These relays are fed off oil 'bus

* The unit was manufactured by Electronic Products Ltd., Rugeley, Staffordshire.

† An electronic "valve" is, of course, a "tube" in America; and a thyratron valve is simply a grid-controlled arc tube.

mains * which in turn are connected to the central oil pressure reservoir by solenoid-operated master control valves in the hydraulic cabinet in the switchgear room. The master control valve (one for each valve function: inlet opening; inlet closing; air opening; and so forth) are also energized as appropriate by the sequencer. All valves are automatically locked in position unless oil pressure is actually being supplied.

This central cabinet comprises an oil pressure reservoir, with a nitrogen cushion (air cannot be used as it oxidizes the oil), the reservoir being topped up † automatically by one of two electrically operated pressure generators, with, in addition, a hand-operated pressure generator for emergency use.

Each filter valve is provided with an electrically operated valve position transmitter wired to an indicator dial on one of the two side control tables in the administration hall (Fig. 4). The transmitter operating mechanism designed especially for Broadside comprises a friction roller on the valve spindle working through a cam and pushrod.

Pneumatic control tends to suffer from corrosion troubles caused by dampness in the air, and water pressure control has its troubles also from corrosion and freezing. It is difficult, in both, to maintain leakproof control cocks, and no satisfactory method of locking valves in position appears to have been developed so far. The oil hydraulic system does not suffer the shortcomings of the others and does not seem to have replaced them with shortcomings of its own.

Filter Flow Control

The output of each filter is governed by its 12-in. module automatic flow controller (*see* Fig. 5) which can be set to any desired output and which maintains this output constant irrespective of variations in the filtering head loss. It was originally accepted that, although all other filter controls had been taken back to the administration hall, there would still be headstocks ‡ along the filter control galleries with spindles down to the pipe gallery for direct setting of the modules.

Following discussion on this point, however, the filter plant contractors developed a remote-control hydraulic jacking system operated from the side control tables in the administration hall adjacent to the automatic sequencer. The remote setting of the modules is carried out by push-button control of a small electrically driven oil pressure pump through the jacking system; but, no doubt because of a distrust of anything new, the overriding hand controls have been left on the slow-start tanks for emergency use.

Electrical transmitters at each module are wired to indicating dials for module setting and filter rate of flow. Each filter has, then, on its own section of the side control-tables: a clarity bowl; a loss-of-head indicator; a rate-of-flow indicator; valve position indicators for inlet, upwash, air, and wash-

* A 'bus main, or omnibus main, is more commonly called a "feeder main (or conduit)" in America. Those here referred to are oil pressure conduits. There are ten of them: one supplies pressure for the hydraulic relay; eight (four pairs) connect the relay with the inlet, washout, upwash, and air valves; the other provides a common exhaust.

† To say that the pressure reservoir is "topped up" automatically merely means that when the pressure in the system falls, as it must through sweating joints or otherwise, the small pump delivers such additional hydraulic fluid into the reservoir as is necessary to restore the pressure. Normally the pressure is maintained at 1,000–1,200 psi, and when it falls beneath 1,000 psi the pump automatically comes into operation, shutting off again when the 1,200 psi has been restored.

‡ A headstock is merely an arrangement for housing gearing and a hand wheel for remote control of a sluice valve or the like.

out valves; and a module setting indicator.

Each module works in conjunction with an automatic slow-start tank (Fig. 6), which functions as follows:

1. It closes the module automatically when emptied under the control of the pilot float in the filter when the filter has drained down to the level at which it can be washed.

2. It brings the filter slowly into operation after washing over any desired period of 5–30 min. The time is preset on the time-regulating valve controlling the inflow of water to the tank.

3. It shuts down the filter automatically and maintains the filter bed waterlogged, should the raw-water supply cease for any reason. It is this last function which has been utilized in the automatic shutdown and restart.

Automatic Filter Washing

The arrangement for automatic filter washing, which was first designed to meet the Broadside specification, is probably the plant's most interesting feature. The same arrangement has, however, been installed since 1952 at six plants in Great Britain, one in Africa, and one in New Zealand.

Instead of a series of conventional cabinets in front of each filter from which valves are operated by remote control, either manually or by electric push-buttons, the entire filter-washing process is controlled from a central sequencer (Fig. 7), in front of the meter panel in the administration hall, designed to control the ultimate twenty filters, but at present only working on twelve. Each filter has an electrically operated loss-of-head differential transmitter wired to its dial on the side control table and also a differential pressure switch which sends a signal through to the automatic sequencer when the predetermined head loss at that particular filter has been reached. The number of the filter is then sought out on one of the central indicator dials. That particular filter is then connected to the hydraulic pressure system through its filter bed selector valve, and the filter-washing process is carried out automatically.

The sequencer makes use of standard automatic telephone relays, switching units, and selectors to General Post Office specification, and special automatic timers which were developed for use with this particular equipment. It carries out the following nine duties:

1. *It washes the filters automatically in the order in which they present themselves for washing.* If other filters present themselves simultaneously or while one filter is being washed, they are stored in a queue. The washing sequence is as follows:

a. The inlet valve closes. The filter then drains down into supply until the water level reaches weir level. The pilot float falls and opens the drain valve, thus emptying the slow-start tank and shutting off the module. The module is arranged to close droptight, thus saving a separate sluice valve.

b. The washout valve, in the washout bay, opens and drains down the weir chamber.

c. The air scour valve opens.

d. The air blower starts and scrubs the sand grains for a predetermined time, normally 4 min.

e. The air blower stops.

f. The air scour valve closes.

g. The upwash valve opens by the predetermined amount to pass 3,420 gpm through the filter bed. This upwash continues for a predetermined time, normally 4 min.

h. The upwash valve closes.

i. The inlet valve opens and water, guided by the deflector plate, sweeps across the sand bed and provides a surface flush.

j. The washout valve closes.

k. The filter fills up; the pilot float rises, closing the drain valve and allowing the slow-start tank to fill under the control of its time-regulating valve. The module then opens gradually to bring the filter into operation.

2. It provides automatically for a delay of 20 min after completion of one filter wash before commencing to wash the next filter, in order to allow the first filter to reach full output. In emergency, this delay can be set to 2 min.

3. *It provides a means of varying the duration of air scour, upwash, and surface flush through the process timers.* This is achieved by means of pre-setting switches, which can vary the period of time from 1 to 10 min in each case.

4. *It provides for failure of the electricity supply.* Should the electricity supply fail while the filter is being washed, and should this failure occur during the application of the upwash, the sequencer recloses the upwash valve before going out of service. When the

Fig. 4. Central Control Group, Administration Hall

A unique feature of the Broadside plant is that practically all the instruments for the entire plant (including individual filters) have been grouped at one point in the center of the administration hall, thus permitting the state of the plant's operations at any particular moment to be seen at one glance. The automatic sequencing console is shown in left foreground, between the two side control tables and directly before the main meter panel.

electricity supply is restored the sequencer then goes back to the commencement of the wash and rewashes the filter. Should the failure occur after the upwash is complete, the sequencer, when the supply once more becomes available, merely carries on with the wash.

5. *It provides for manual selection.* By means of the master control switch and its own manual selector switch, any filter can be brought in for washing manually and left to wash automatically.

6. *It provides for manual washing.* Again by proper positioning of the master control switch, any filter can be selected manually by its own manual selector switch and each of the various filter valves can be operated under manual control through their own appropriate switches on the sequencer.

7. *It provides for alteration in the sequence of washing filters already in the queue.* To illustrate the flexibility of this arrangement, let us assume that Filter No. 8 is washing and filters No. 12 and 18 are in the priority queue. For some particular reason it may be desirable to wash No. 14 immediately after No. 8. Filter No. 12 is then isolated and cancelled by hand, and No. 14 is selected manually and takes its place on the central indicator dial vacated by No. 12. Filter No. 14 will then wash immediately after No. 8; then No. 18; and then No. 12—No. 12 automatically retaking a place in the queue after No. 18. The order of washing will now be: 8, 14, 18, and 12.

8. *It gives warning of any untoward happening.* The sequencer is equipped with alarms both visible and audible, to indicate failure of the oil pressure system or of the electrical supply, and a master cancelling push-button is embodied in the top panel, which enables the washing process to be cancelled at any stage.

9. *It insures that each operation is complete before another starts.* An automatic timer is incorporated to insure that each valve has reached the end of its travel before the next stage of the washing sequence commences. It was originally expected that the hydraulic valves could take up to 90 sec for complete opening or complete closing, and the automatic timer was designed to maintain the oil pressure for 2 min. In actual operation it has been found that this is a rather generous allowance, and the time could have been shortened, still leaving an ample safety margin.

Signal lights indicate which filters are working normally and which filter is being washed, while the first two filters in the queue have their numbers indicated on the central indicator dials. The time at which each filter is washed and the length of time occupied are recorded on two multipen program recorders on the main panel.

The signal light system operates on 230-v alternating current. All control relays and solenoids are operated on 50-v direct current from a central battery. Loss-of-head indicators and the other filter instruments and transmitters operate on 12-v direct current from a separate battery unit. Both sets of batteries are kept up by automatic trickle charge.

No attempt has been made to teach the sequencer to talk. This may well be considered one of its main advantages over human control.

Automatic Shutdown and Restart

With an ultimate flow of 21 mgd through the plant, it was realized that the overflow which might result if the clear-water tank filled during the night

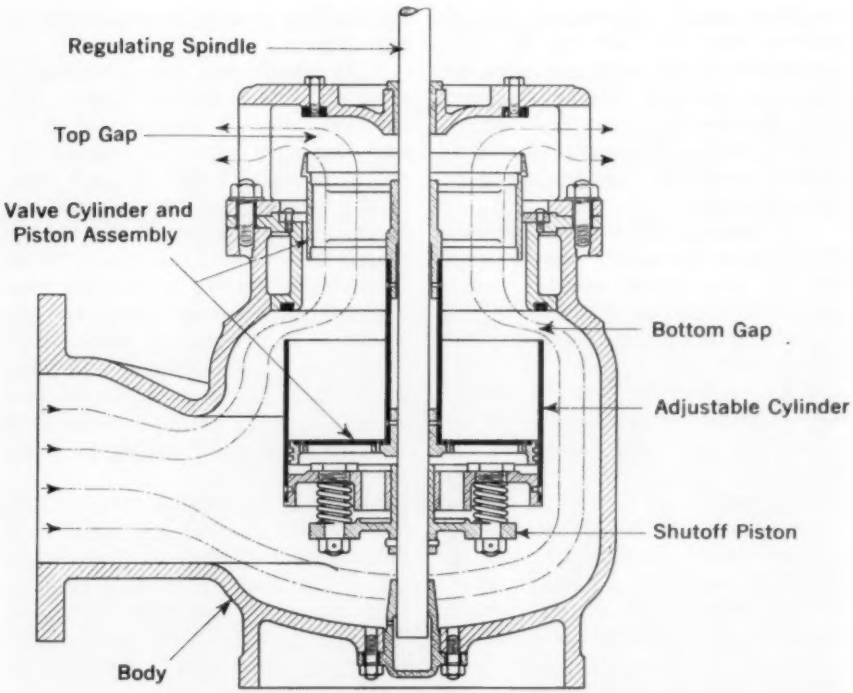


Fig. 5. Module Automatic Flow Controller

As well as maintaining a constant rate of discharge, the module performs the function of a stop valve and provides an indication of the flow. In order to pass through the bottom gap, the velocity of the water is compelled to increase, causing a pressure decrease. At a critical velocity the pressure difference is sufficient to balance the weight of the piston and valve cylinder assembly, which then floats. The valve cylinder is of the balanced type, so that the force required to raise it remains constant irrespective of the pressure of the water inside the module or the drop in pressure across the top gap. Consequently, the bottom gap maintains accurate control of the flow, as the slightest increase or decrease in the critical velocity causes the piston and valve cylinder to rise or fall, thus increasing or reducing the throttling of the top gap to restore equilibrium. If a different rate of flow is required, the bottom gap is altered by turning the handwheel. The module shown was developed and is manufactured by the Candy Filter Co., Ltd., Hanwell, London.

was something to be avoided. Obviously, some arrangement for shutting down the plant and again reopening automatically was imperative. It seemed that the most reliable and foolproof form of energy for this operation would be hydraulic.

Figure 8 diagrammatically illustrates the arrangement. A master slow-start tank was installed in the administration basement; this takes its water supply from the wash water tank in the roof, and delivers water to the individual slow-start tanks at each filter. The

drain valve for emptying the master tank also empties each individual tank through a reflux valve. In the floor of the administration basement there is a float well at the same level as the clear-water tank, to which it is connected by means of a 6-in. diameter pipe. At the clear-water tank there is a small delay tank set with its lip near top water level and with a 4-in. diameter ball valve at the bottom for draining. This is the same type of tank which is common on service reservoir inlets, to provide steady opening and closing of large valves. The shutdown and restart are each accomplished in two stages. The two stages of operation are as follows:

1. When the clear-water tank is nearly full, water spills over into the delay tank, filling up the float well in the administration basement. The float rises and lifts the master drain-valve operating lever, draining all the slow-start tanks and causing all the filters to close down simultaneously. The same operating lever holds the ball tap on the master slow-start tank shut while the drain is open.

2. On the inlet side of the filters, after the filters have shut off, the water level will continue to rise until the inlet valves are shut. As the water rises, its level in the settled-water channel is communicated hydraulically through a 6-in. diameter pipe to the float wells to close the two equilibrium valves at the inlet, thus shutting down the whole plant.

For restarting, the system operates in reverse:

1. The clear-water tank falls in level by 1 ft; the delay tank ball valve opens, draining the delay tank and the float well. The master slow-start tank is refilled and all the filter modules reopen through the slow-start tanks, controlled by the individual time-regulating valves, thus avoiding any difficulties which could otherwise occur if the full flow were suddenly applied to the plant.

2. The reopening of the filters causes a drop in level in the settled-water channels, lowering the inlet float wells and reopening the equilibrium valves.

In designing the system, considerable care had to be taken with the hydraulic side of the operation as there is necessarily a time lag in shutting which governed the level of the overflow sill in the clear-water tank. By using a 6-in. diameter pipe (instead of the 4-in. pipe originally suggested) between the clear-water tank and the float well, a saving in time of 1½ min was achieved. This saving is important, as the level of the clear-water tank rises 1.3 ipm. The overflow sill could then be placed so that inflow is normally stopped before overflow level is reached. Also the full discharge head for a flow of 21 mgd over the sill is available before water reaches the underside of the roof.

Electric Supply

Dependent as it is on electricity, the operation of the whole station could be disrupted by failure of the mains.* The total load on the station is of the order of 47 kw, but approximately 25 kw of this is taken up by the air blowers and by a number of nonvital pieces of plant, such as the sampling pumps, laboratory equipment, lighting, and other equipment. The station can thus be run, and washing can be carried out without air scour, on a load of 22 kw. An a-c diesel generator covering this supply is installed in the administration basement.

The electrical wiring contract provided for the making, by the contractors, of a full investigation of power fac-

* "Main" is commonly used in Britain (and infrequently in America) to apply to any principal line, conduit, or conductor in a system of distribution. In this instance, of course, an electric power line is intended.

tor, in respect to each item of plant, before the end of its maintenance period. Payment for the supply is by maximum demand (kilovolt-amperes) and not by kilowatts, and it was felt that any saving resulting from power factor correction deserved consideration. As a result, static condensers were installed, improving the power factor from 0.80 to 0.97. The cost of these condensers and their installation will have been saved before the end of 1956.

TABLE 2

Operation of Alarm System

Alarm	Method of Operation
Abnormally high or low level in settling tanks	Electric differential switches
*Failure of flash-mixer circulating pump	Contact on starter to signal if starter trips: interlocked so that only the running pump starter is operative
Overflow or abnormally low level in clear-water tank	Contacts on level indicator
Overflow or abnormally low level in wash water storage tank	Contacts on level indicator
Abnormally high or low level in draw-off sump at sludge lagoon	"No float" switch control
Abnormally high or low chlorine residual	Contacts on chlorine residual recorder
*Failure of alum, soda ash, or other coagulant dosage	Drop in pressure in small air-vessel on chemical delivery line operates electric pressure switch
Low pH value	Contacts on pH recorder
Failure of oil supply to heating boiler	Contact on photoelectric monitor‡
Failure of pressure on oil hydraulic system†	Electric differential-pressure switch
Failure of electric power supply	Relay making an alarm circuit contact and disconnecting alarms marked * which would otherwise give alarm
*Auto-sequencer electric supply, both line and battery	Relay in sequencer

* Alarms automatically disconnected on failure of electric power supply.
† The system uses Lockheed hydraulic equipment, manufactured by Automotive Products Co., Ltd., Leamington Spa, England.
‡ The Radiovisor unit, a product of Radiovisor Parent Ltd., London, is used. This unit comprises a photoelectric cell with infrared filter mounted on the front of the oil-fired central heating boiler. The relay is held closed so long as light from the flame is being received by the photo cell. Should the light fail, the relay closes the solenoid-operated valve and shuts off the oil supply, ringing the alarm at the same time.

Alarm System

The plant is not staffed during the night, and it was never intended that it should be. Also, keeping in mind the distance which the day staff might be from the point of any breakdown, a comprehensive range of alarm signals was designed and mounted on the main meter panel. The signals are given by means of indicator lights, and a klaxon horn supplies the audible warning. A small replica of the panel, incorporating indicator lights and a bell, is provided in the attendant's house. A full list of the alarms and the methods of operation is given in Table 2.

When the plant closes down as a result of a rise in the level of the clear-water tank as described, the draining of the master slow-start tank also operates a float switch to shut off [1] the

flash-mixer pump, [2] the motors driving all chemicals, and [3] the chlorinator; it also disconnects all appropriate alarms, as indicated in Table 2.

Operational Troubles

It would have been quite exceptional if such a plant, which was new in so many features, had gone into service without some troubles arising. These troubles, detailed under the seven headings below, have been very few in number.

Automatic Shutdown

Despite the fact that this whole arrangement was considered foolproof, overflow weirs were provided on each side of the plant from the raw-water channel, each overflow being capable of spilling 10.5 mgd with a head of 4¾ in. The overflow weir at the clear-water tank inlet can spill the full capacity of 21 mgd.

In January 1953, the plant was running with the building contractors still on the site and, although the outlet shutoff arrangements were all connected up, the control floats on the inlet valves had not been adjusted at that time. One morning, about 4 AM, the clear-water tank filled, and the outlet shutoff arrangements worked perfectly at the first trial. There was, unfortunately, no means of communicating that fact to the inlet valves. The water level in the filters and raw-water channels rose, and, to complete the chapter of accidents, the building contractors had made a mistake in the level of the west overflow sill, which was about 4¼ in. higher than the designed level. The result was that, at 7:30 AM, water was cascading into the pipe gallery through the 2-in. diameter holes carrying the slow-start pilot float chains. The loss-of-head transmitters were housed in sumps beside the module chambers, and these had to be returned to the makers for drying. The transmitters have now been relocated above floor level.

Alarm Systems: Failure of Coagulation

Initially it was intended that the alarms for failure of alumina and soda ash would make use of feed tanks and float switches; but, after installation, this arrangement suffered from troubles due to air locking which could not easily be overcome.

This portion of the system has been redesigned and now makes use of a small pressure vessel and rotameter in each feed line, with a differential switch to make contact when the pressure in the vessel falls below the predetermined limit.

Inlet Venturi Meter

For many months the transmitter on the 4-in. bypass venturi meter would not operate properly and, after several dismantlings, it was finally discovered that there were small fibre roots in the annular ring of the Dall tube* at the throat. Once this tube was cleared out the meter started to register perfectly and now gives no trouble.

Electric Equipment

Trouble has been experienced to a small, but nevertheless annoying, extent by the burning-out of about six small electric motors and similar units; this has been proved to be caused by voltage surge. The air blowers are, of necessity, provided with direct-on starters, and it was felt that the trouble was caused by these units, and no doubt they are partially responsible. Arrangements are being made at the mo-

* The Dall tube is a shorter and less expensive form of venturi tube. It was designed by a member of the staff of George Kent Ltd., Luton, Bedfordshire, by which firm it is marketed.

ment, however, for the electricity authority to install a larger mains transformer on their side of the supply, as the present transformer is definitely too small for its work.

to cover nothing; and economically the latter arrangement has much to recommend it. The filters, having a downward velocity of three times the upward velocity in the settling tanks, are

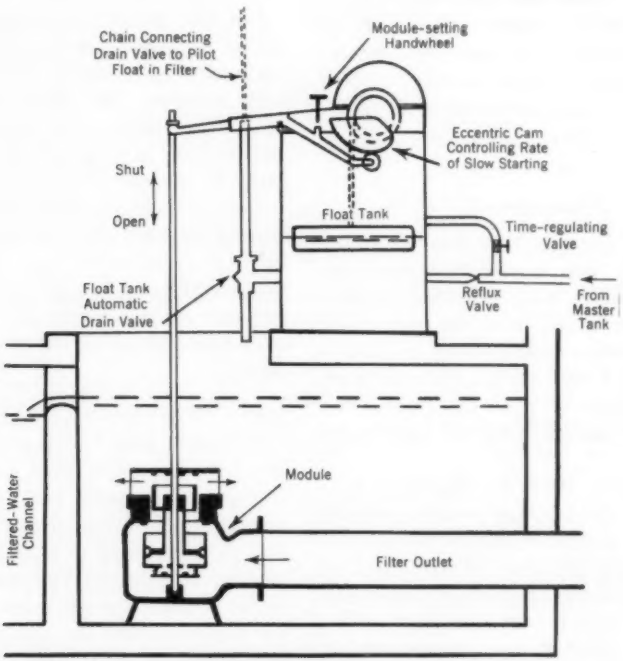


Fig. 6. Operation of Module With Automatic Slow-Start Control Tank

Each module works in conjunction with an automatic slow-start control tank which closes the module automatically for washing, brings the filter slowly into operation after washing, and shuts down the filter automatically if the raw-water supply should cease for any reason.

Freezing

The possibility of the filters freezing if they were not housed was raised with the author by a number of colleagues early in construction, but the alternatives were either to cover the whole plant, including the settling tanks, or not the more vulnerable of the two sets of units.

So far, during the operation of the plant, the lowest persisting temperature which has been experienced is 18°F, and it is unlikely that there would ever be any extended period dur-

ing which the temperature would be much lower.

Inlet valve floats. During very hard frost it has been necessary to hang open braziers inside the inlet valve float wells and, at the same time, partially to cover the wells. This has been effective in keeping the floats free.

Settling tanks. Fairly thick ice has formed on many occasions, but, despite this, the flow has not been affected as the water has continuously run from under the ice through the serrated notches in the edges of the decanting troughs. For structural considerations, it is advisable to keep the edge of the ice broken; but the mistake was made on one occasion of trying to break up all the ice, with the result that the ice only formed more thickly, and indeed, on that occasion, practically stopped the flow through the tanks concerned.

Filters. When ice forms on the filters it is broken away from the wall by hand, but one unforeseen trouble has been experienced. The pilot floats for the slow-start tank drains communicate with the filter by means of chains coming through from the pipe gallery just under the filter walkway. When all the filters are frozen, and the ice is floating, and one filter on that side is washing, it has been found that the action of opening the inlet valve, for surface flush and to refill, has the effect of drawing down the level in the settled-water channel temporarily by 4–6 in. As the water in each of the filters communicates directly with this channel, the filter levels fall by the same amount, dragging the ice down at the same time. With the pilot float chains embedded in the ice, it can easily be seen that the chains are pulled down, opening the drain valves and shutting off the filters. Having been caught once in this manner the same trouble should not be experienced again. In any future plant the pilot floats would be housed in float wells in the pipe gallery.

Valve position indicators. As described earlier, the transmitters for the valve position indicators pick up their signal from a friction roller operating on the valve spindle. For some reason or other, condensation seems to take place on the spindle, above the roller, in the case of both the washout valve and the inlet valve, which are outside in the open. When frost occurs, the bead of condensation freezes, preventing the roller from turning and causing it to slide. This unexpected mishap is being corrected now.

Filter Distributing-Channel Wall

When designed, the entry to each filter was chamfered downwards into the distributing channel, and the top of the wall of this channel was finished at a level about three-quarters of the way up the penstock. With manual operation this would have been quite satisfactory, since the valve could then have been opened partially until the filter was filled and the opening completed later. The automatic sequencer finishes the job in one operation, however, and, with the valve fully open and the filter empty, there was considerable splash over the top of the distributing-channel wall and on to the sand. The distributing-channel walls have all been raised by 2 ft immediately opposite the inlet penstock.

Automatic Sequencer

The sequencer has given little trouble apart from replacement of one faulty solenoid, and one complete breakdown caused by dampness. Owing to a fault discovered in the oil pump to the boiler, the plant was nearly 6 weeks without heating at the beginning of the winter,

and a few weeks later the sequencer broke down. The additional precaution has now been taken of maintaining calcium chloride jars in the cabinet.

Readings given by such meters are not usually much closer than this, unless by chance, when they might be equally wrong, so that to determine the volume

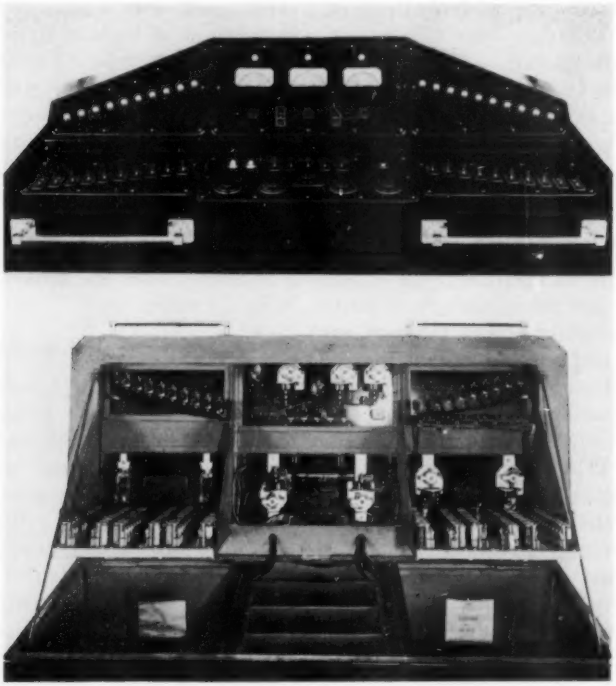


Fig. 7. Automatic Sequencing Console

The upper half of the illustration shows the top of the console, on which the time-setting switches, selector switches, and dials are apparent. Lower half is the interior view of the console with the top thrown back, showing accessibility of the solenoids, selectors, and other components.

Waste Water Losses

A comparison between the inlet and outlet venturi meters and the meter 3 miles down the main from the works shows a discrepancy of 4–5 per cent. It is known that the meter on the line consistently tends to read 1–1.25 per cent below the combined readings of the other three meters on the main. of water passing through the plant, the average of the upper three meters has been taken. Flows of wash water, supernatant return water, and sludge bleeds, have been determined for a number of periods of 14–28 days, but they all give substantially similar results. The period Nov. 7–21, 1955, has been taken as standard. During

that time the water passing through the plant amounted to 93 mil gal.

There are four sources of feed water to the sludge lagoons: the wash water, which is metered; the sludge bleeds, which have, from time to time, been measured by quantity; the surface flush, which passes directly to the drains and which has been calculated by depth over the weir sill in the filter; and the underdrains of the plant, which, although there to pick up any underground water, also pick up any leakage and miscellaneous water used on the plant itself.

Miscellaneous water includes such things as leakage from drain valves, the observation bowls, laboratory sampling taps, and other minor uses. These have been measured in the aggregate and checked individually so far as possible. The sludge-bleed quantity varies considerably, even if the drawoff valves are not interfered with, because the actual discharge varies from a fairly thick sludge to the clarified water. This is because the sludge goes over the sludge-bleed weir very often with a billowing effect, and is not a steady "bleed" as the word would suggest. The average quantity from the 24 tanks with the bleed pipes running half open has been found to be about 276,000 gpd.

Over the standard fortnight the total water finding its way to the sludge lagoons is 4,883,000 gal, of which 703,000 gal is wash water, 3,864,000 gal is sludge bleed, 144,000 gal is surface flush and 172,000 gal is from underdrains and miscellaneous uses.

During the same period the water returned from the sludge lagoons for refiltration amounted, by meter, to 4,643,000 gal and the discharge of water and sludge from the sludge lagoons by capacity measurement, allowing for sludge-bleed flow during discharge, amounted to 239,840 gal. The latter figure is the net loss through the plant, and amounts to 0.26 per cent of the water leaving the plant.

Without returning the supernatant water from the sludge lagoons for refiltration, the total loss would amount to 5.25 per cent, but, from experience, it is possible to run the sludge bleeds at a figure much lower than that at which they are normally operating. The more the sludge-bleed water is cut down, the greater is the tendency for the drawoff pipes to choke and, despite the fact that they are very easily cleaned from that state by rodding, it has been felt that it is cheaper to circulate the extra water internally within the plant than to keep personnel constantly on the watch for choking sludge bleeds. With this sludge-bleed flow the main desludging pipes are only used when a settling tank has to be emptied.

It has been found that an upwash period of 4 min is ample, when following an air scour of the same duration; and this time, when coupled to the opening and shutting lag of the control valves, gives an average figure, for the 50 filters washed during the period under review, of 14,060 gal per wash. The average run of the filters at present flow is about 81 hr between washes.

Comparisons have been made with some of the filters running at their full designed rate and also washing at a head loss of 6 ft. The average length of filter run does not appear to be materially affected. This result appears to call for, and must receive, further investigation.

At present flow, approximately 53 per cent of the designed rate, the filters are normally much dirtier when the 6-ft head loss is reached than is the case with this head loss at the full flow. At the full rate, a filter drains down into supply for washing in about 25 min,

while at half rate it requires approximately an hour for the same operation. The 4-min upwash is sufficient whether the filters have been operated at full or half rate.

When the plant is operating at the full rate, even if the filter run figures given above are proved to be spurious, the wash water and surface flush can, at most, only double; and, since the present sludge-bleed drawoff is at the very high rate of 8 gpm per tank, it has been proved that this will not need to be altered at full flow. Consequently, it can well be expected that the total waste water with the plant in full operation will not exceed 3.25 per cent, which compares very favorably indeed with filters using other forms of presettlement and high-velocity wash.

The supernatant water from the sludge lagoon will still form an internal circuit in the plant, but there is not likely to be any reduction below 0.26 per cent for the actual waste discharged. It is to be expected that the quantity of sludge to be disposed of will vary with the amount of water passing through the plant, and that sludge always requires a minimum of water to make it fluid for disposal.

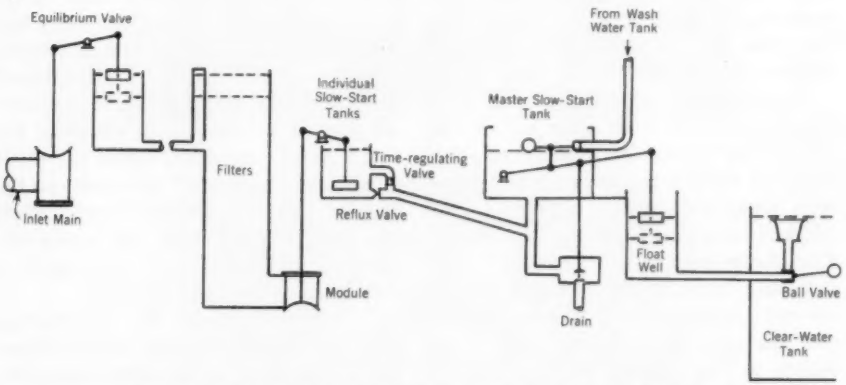


Fig. 8. Arrangement for Automatic Shutdown and Restart

As it is not intended that the plant should be staffed throughout the 24-hr day, it has been necessary to provide for automatic shutdown in the event of the clear-water tank filling during the night. To achieve this, the level of the clear-water tank is connected to a special chamber in the administration basement and a float in this chamber rises to shut off all the filter outlet modules. Then, as water rises in the settling tanks, the level is translated back to the inlet where the float valves close on the plant inlet main.

Personnel

As has been mentioned, the plant and grounds receive attention only during the 8-hr day, the total staff consisting of chemist, plant attendant, and three laborers. No exceptional skill is necessary. The plant attendant is an old employee of the board, a fitter * by

* A tradesman engineer in Great Britain serves his apprenticeship as a "fitter" and "turner," so that, as an engineer, he is capable of both making and assembling engineering parts. A turner is, of course, a lathe operator; while a fitter would probably be described as a mechanic in this country.

trade, who had spent 17 years as a pressure plant attendant, and has received no special training on this plant except for the fact that he was on the plant for a period while the contractors were completing the installation.

The control, while complex, is not complicated, there being nothing in the way of new design in any of the electrical units. The board has a contract with the electrical contractors by which, for a lump sum per year representing less than one-twentieth of a man's gross annual wages, a semiannual inspection is made and a report given. They also undertake to make the foreman who installed the equipment available on call. Similarly, the firm which built the automatic sequencer has a maintenance contract with the board.

Cost

It would not be ethical to quote the cost of the automatic control of this plant, since much of it was experimental and the filter contractors tendered their bids without being wholly certain of how they were going to meet the specification. The cost of the plant described cannot, in that case, be taken as standard. Without automatic control, four other men—two per quiet shift * would be required, and the capitalized value of their gross emoluments far exceeds the difference in cost between automatic and manual control.

In the automatic washing, twelve control cabinets have been replaced by one rather more involved cabinet; and the only other cost is that of extra hydraulic tubing, electric transmitters, batteries, and wiring. The running cost is negligible.

* Quiet shifts are the two 8-hr periods outside the regular working day.

Research

The equipment throughout the plant has been designed so that it can be operated at higher ratings and consequently a higher total flow through the plant, and it is the intention of the board to carry out research to determine the highest permissible rate of flow in practice. Items scheduled for immediate consideration are: [1] settling tanks (upward velocity); [2] filtration rate; [3] the relative merits of deep and shallow settling tanks; and [4] chemical treatment.

In connection with the last item, the plant will allow a switchover to any type of treatment involving solution feed; and experiments will be carried out, using different chemicals, to determine the most satisfactory from the viewpoint of effective results coupled with economy.

Acknowledgments

The author is grateful to the Stirlingshire and Falkirk Water Board for permission to publish this paper, and to his deputy, S. D. Mitchell, and other members of his staff, as well as to J. H. T. Griffiths of the Candy Filter Company, London, for their ready and willing assistance and suggestions while the paper was in draft form.

EDITOR'S NOTE: *The author invites queries or comments relating to the subject of this article. Correspondence should be addressed in care of Journal AWWA, 2 Park Ave., New York 16, N.Y.*

Conductivity-Difference Control of Chemical Coagulation

R. H. Babcock and K. F. Knowlton

A paper presented on Apr. 4, 1956, at the Pennsylvania Section Meeting, Philadelphia, Pa., by R. H. Babcock, Asst. Mgr., Utilities Industry Div., The Foxboro Co., Foxboro, Mass.; and K. F. Knowlton, Supt. and Chemist, Salem and Beverly Water Supply Board, North Beverly, Mass.

IN recently published literature, the use of electrical conductivity in the recording of fluoride additions to water was discussed (*1*). These data were later extended in connection with the control of the fluoridation process (*2*).

The measurement of electrical conductivity has long been applied as a laboratory routine. It has also been used frequently in industry for the control of dilution operations, concentration operations, detection of contaminants, and other similar applications. The measurement of conductivity as part of the routine analysis in water works, however, has been adopted at very few installations.

It is well known that an electric current will pass through water more easily after a salt has been added to the water. The addition of any material which ionizes in water will have the same effect to some extent, and instruments have long since been developed to measure minute changes in the electrical conductivity of water. Procedures and definitions have been adopted for discussing these phenomena.

Electrical conductivity is the reciprocal of electrical resistance—that is, one divided by the resistance expressed in ohms. The word "mho," which is "ohm" spelled backwards, is used to express units of conductivity. Specific conductivity is the conductivity at a given temperature of the material under test as contained within a volume of unit cross section and unit length. Since the conductivity is usually low, the resistance being high, it is expressed in micromhos, which are millionths of a mho.

Salem-Beverly Study

A study of the application of this measurement as a means of detecting the amount of fluoride added to the water supply at the Salem and Beverly Water Supply Board, North Beverly, Mass., was first undertaken in the latter part of 1952. The change in conductivity caused by the addition of a salt of fluoride to the water supply was measured, the conductivity being determined both prior to the point of application and after the point of application. The two measurements were electrically subtracted and the net difference in conductivity was recorded by the method shown in Fig. 1. A record from the instrument is shown in Fig. 2.

Following the initial investigation, the instrument was modified to operate as a controller with the flow from the fluoride feeder regulated by a pneumatic control valve operated by a pneumatic conductivity-difference controller. This installation has been in service for several years.

In January, 1955, the Salem and Beverly Water Supply Board changed from the use of dry powdered alum to the use of liquid alum for the coagulation portion of its filtration process.

This change called for installation of an alum storage tank on the top floor of the filter building. The alum solution is fed through a pneumatically controlled valve to an injector which dilutes the syrup and feeds it into the raw-water pipeline.

Interest in other applications of conductivity difference measurement was stimulated to some degree by work done at the Rand Water Board, Transvaal, South Africa, where conductivity was used as an index to achieve good chemical coagulation for a great number of years. Facilities for experimenting with conductivity control of the coagulation process became available at the Salem-Beverly plant when the changeover to liquid alum took place. The initial installation had used pH to operate the pneumatic control valve on the line from the elevated storage tank to the plant influent. To operate from conductivity difference, it was only necessary to substitute a conductivity-difference controller in place of the pH controller. A conductivity cell was inserted in a sample line coming from a point ahead of the point of alum addition and another cell was inserted in the treated-water line following the point of alum addition and just prior to the point where the flow entered the coagulation basin. In essence, the system, as shown in Fig. 3, looks very much like the one previously described for fluoride addition control, except that the controlled medium is liquid alum.

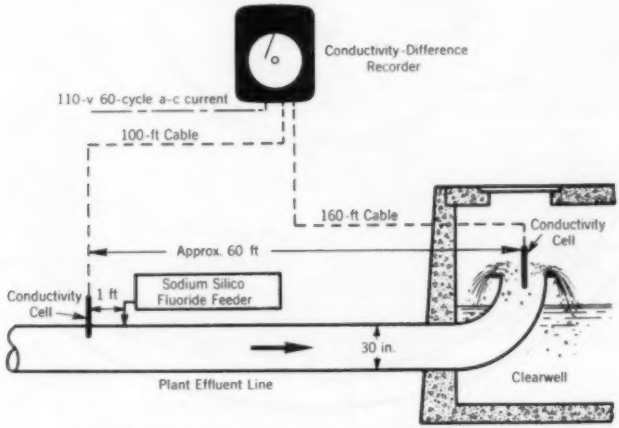


Fig. 1. Recorder for Conductivity Difference

Laboratory Use

Before giving a detailed discussion of applications in the water works field, the use of conductivity measurements in the laboratory will be reviewed (*3, 4*). If a solution of strong acid is gradually neutralized by a strong base such as sodium hydroxide, the hydrogen ions of the former are replaced by the metal ions of sodium having a much lower conductance. The conductance of the solution will therefore decrease steadily as the base is added. When neutralization is complete, the further addition of alkali cannot remove any

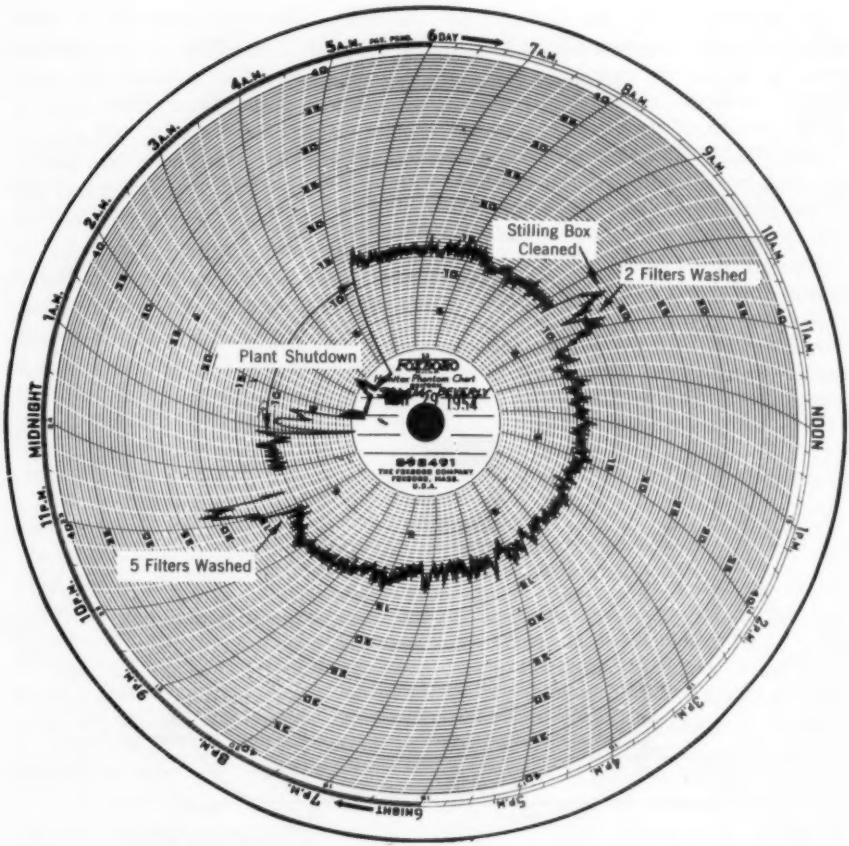


Fig. 2. Record From Conductivity-Difference Recorder

more hydrogen ions and the conductance will no longer decrease; in fact, it will increase because of the excess of the strong base now present in the solution. It follows, therefore, that the variation of the conductance with the addition of alkali will be as shown in Fig. 4, Curve *A*. The minimum corresponds to the equivalence point—that is, the theoretical endpoint of the neutralization. These curves show that the conductance measurements can be used to determine the equivalence point of the strong acid base titration. The conductance is measured at two points at the sides of the equivalence point as known amounts of alkali are added. Lines are then drawn through these points and the intersection of the lines determines the required end point. Therefore, if a very weak acid such as boric acid or phenol is used, the initial decrease of conductance upon neutralization is not observed, being of the type shown in Fig. 4, Curve *B*. In each case, the endpoint is determined by the intersection of two almost straight lines, but only if the volume change is kept small.

With chemical coagulation, it is usually considered that a weak base is titrated—that is, the alkalinity of the water with a weak acid, the alum. The result is a curve similar in shape to that illustrated by Curve *B*, Fig. 4. With this method, conductivity is used to detect the endpoint of a reaction, whereas, in the jar test, essentially the observation of a physical phenomenon is used (the formation of a suitable floc) to detect the endpoint of a reaction. The use of conductivity measurements in continuous plant operation is not practical because of the variation of the water itself. Although the shape of the titration curve will remain exactly the same, its position on the scale of conductance will vary widely. An increase in the dissolved-solids content of the water and the temperature will move the curve up on the scale of conductance.

The use of conductivity-difference measurement eliminates the effect of changes in conductivity of the water. Such items as dissolved gases and dissolved solids are no longer significant because the changes in conductivity are being referred to the base conductivity itself, and it is only the difference produced by the addition of alum which is important here. Temperature is still a variable which can interfere with the measurement but, fortunately, continuous conductivity measurements can be corrected for this variable.

Water Works Application

To determine the appearance of the conductivity curves for the Salem-Beverly installation, an indicating rotameter was installed on the discharge line of the alum control valve. The setting index of the controller was changed in small increments to get a measure of the quantity of alum added versus the change in conductivity difference. Figure 5 shows the rotameter installed after the control valve.

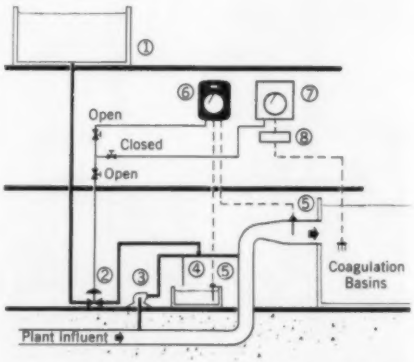


Fig. 3. System for Conductivity Control of Coagulation Process

The keyed numbers indicate the following: (1) alum storage tank; (2) pneumatic control valve; (3) raw-water sample pump; (4) injector; (5) conductivity cell; (6) conductivity-difference controller, 110 v; (7) pH controller, 110 v; and (8) pH amplifier, 110 v.

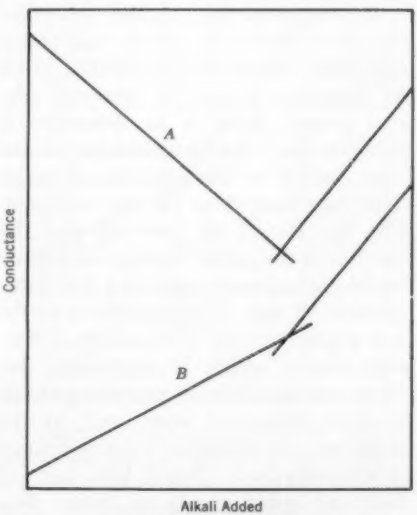


Fig. 4. Variation of Conductance With Addition of Alkali

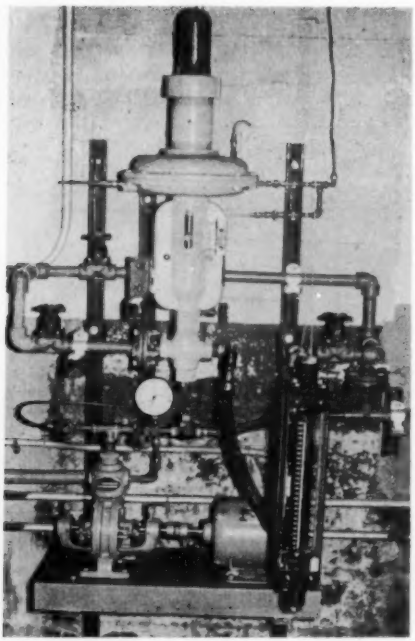


Fig. 5. Rotameter Installed After Control Valve

Plots of the data taken from this phase of the work are shown in Fig. 6.

If the procedure of the analytical chemist is followed, and several points are taken below the equivalence point to determine a straight line and several points above it to determine a straight line, the intersection of the lines would be the equivalence point. This has been done on the curves in Fig. 6. It will be observed that the portion of the curve which occurs prior to the equivalence point has a flat slope. Because of this, it is possible to establish a point on the conductivity-difference curve which is sufficiently far above the equivalence point to provide a slight excess of alum, and, at the same time, be above the expected range of alum required. It will, however, not feed any great excess of alum. For example, a change in measurement of 0.5 micromho represents approximately 4 ppm of alum.

Studies made on the same day, and with the same water as that used for data in Fig 6*a* and 6*b*, were used to run jar tests and to note the point at which the color removal increased markedly. This point occurred at approximately 15 ppm of alum.

The effect of this phenomenon on a different water is discussed in a recent paper investigating the effect of synthetic detergents on chemical coagulation (*5*).

The curves indicate a mechanism which increases the conductivity only slightly, preceding the equivalence point. After the equivalence point, the rate of conductivity increase changes markedly. Perhaps, during the first phase, the aluminum ion is reacting with the alkalinity and the conductivity is being increased only by the sulfate ion. During the second phase, conductivity is being increased by the aluminum ion plus the sulfate ion. Work leading to a theoretical explanation of these observations remains to be done.

In this particular installation, it is not necessary to control the pH of the incoming water because it is reasonably stable and in the range normally found acceptable for chemical coagulation. It has been the practice in the past, however, to control the addition of alum to the water supply in proportion to pH. A curve of this relationship is shown in Fig. 6*c*, illustrating that the change in pH is very small for a marked change in alum addition. This is particularly true when we reach the vicinity of the equivalence point. Because of this, it would appear that conductivity difference provides a more sensitive method of controlling the addition of alum.

The present controller has been in service approximately 6 months. The control of coagulation has been very satisfactory throughout the winter when difficulties are normally at a maximum. Changes in plant flow rate are automatically compensated for.

Conclusion

The data discussed show a completed reaction at a point below the complete utilization of the total available alkalinity. Whether this is a neutralization of the color colloid or some other effect is not known.

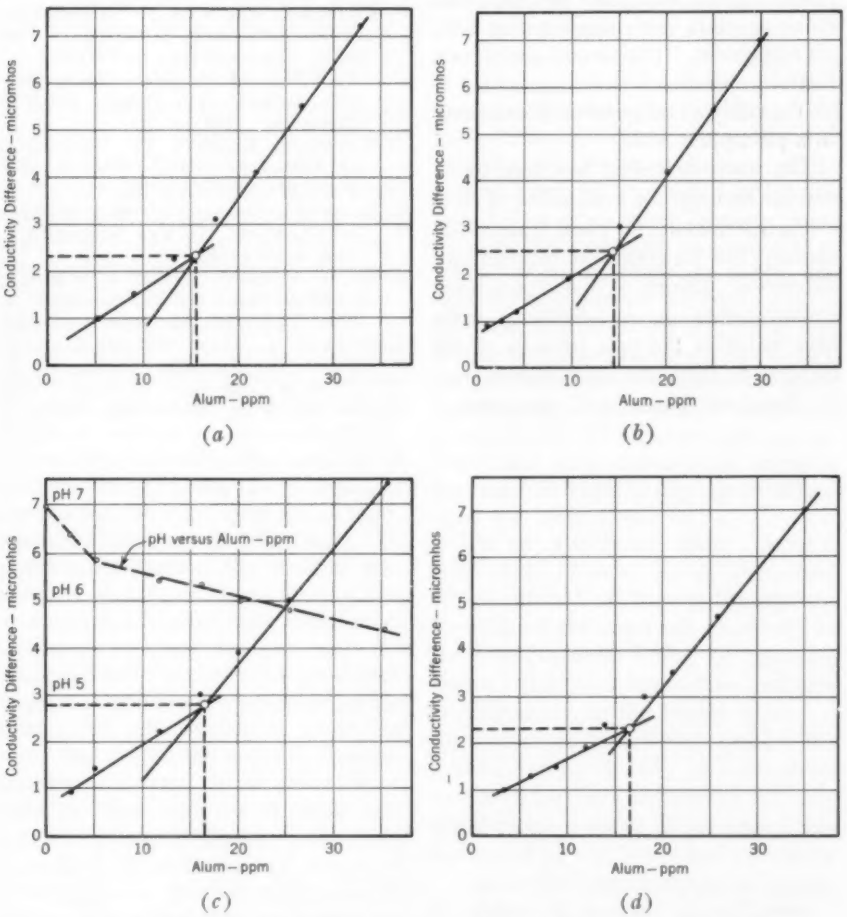


Fig. 6. Conductivity Curves for Salem-Beverly Water Supply Board

The intersections of the conductance lines are at the following points: (a) *15.5 ppm alum and 2.3 micromhos;* (b) *14.5 ppm alum, 2.45 micromhos;* (c) *16.5 ppm alum, 2.8 micromhos; and* (d) *16.5 ppm alum, 2.3 micromhos. Curves in* (a) *and* (b) *are for two tests made on one sample;* (c) *and* (d) *for two tests made on another sample.*

The work to date would seem to indicate that conductivity-difference measurements in chemical coagulation have two separate uses. The first concerns the practical matter of the control of alum dose. For this purpose, the measurements offer a more precise quality control than other methods, and maintenance is much simpler than with pH equipment. The second use of conductivity-difference measurements is for the study of coagulation phenomena on a pilot plant scale.

The work described has been made possible through the availability of electronic instruments for plant scale measurement and for control of conductivity difference. Efforts to investigate these measurements on a laboratory scale have failed in the past because of the inability to eliminate such interferences as dissolved gases and temperature when working with the small changes in conductivity which occur.

It is the authors' hope that this material will be incorporated and expanded in present and future studies of chemical coagulation in water plants.

References

1. KNOWLTON, KENNETH F. Investigation of the Continuous Recording of Fluoride Concentration in Water. *J. NEWWA*, **68**:16 (Mar. 1954); BABCOCK, RUSSELL H. & DOBSON, JOHN G. Discussion. *Ibid.*, p. 32.
2. KNOWLTON, KENNETH F. Fluoridation by Automatic Control. *Wtr. & Sew. Wks.*, **102**:58 (Feb. 1955).
3. GLASSTONE, SAMUEL. *Elements of Physical Chemistry*. D. Van Nostrand Co., New York (1946).
4. *Scott's Standard Method of Chemical Analysis*, Vol. 2. D. Van Nostrand Co., New York (5th ed., 1939). p. 2323.
5. HOWELLS, D. H. & SAWYER, CLAIR N. Effect of Synthetic Detergents on Chemical Coagulation of Water. *Wtr. & Sew. Wks.*, **103**:71 (Feb. 1956).

Pump System Analysis and Planning Methods Used in the Los Angeles City Water System

—Roland Triay Jr.—

A revision of a paper originally presented on Oct. 28, 1954, at the California Section Meeting, Long Beach, Calif., by Roland Triay Jr., Water Works Planning Engr., Dept. of Water & Power, Los Angeles, Calif.

THIS paper outlines some methods used by the Department of Water and Power of the City of Los Angeles to analyze its existing booster pump systems and to plan and design improvements and new pump systems. The subject is described with reference to overall planning, and to the location, size, adequacy, and functional reliability of all facilities, equipment, and controls. Problems in the mechanical design of equipment or the structural design of facilities are not included.

One objective of these methods of analysis and planning is to make it possible for new employees with a minimum of experience or education to do a maximum share of the work of preliminary investigation and preparation of data on a considerable number of problems for final analysis and decision by more experienced personnel. A second objective is to standardize the method of presentation in order to make the results more easily comprehensible. Finally, it is desirable to make the maximum use of actual records and tests, in preference to involved theoretical calculations, as a means of obtaining more reliable results and of quickly educating new personnel on actual operating problems.

Los Angeles City Water System

The story of the water supply problems and city-owned water system of Los Angeles has been well told by many others in past years; only a few of the more important features of the system need to be mentioned at this time. The city's water system serves most of the city area of over 450 sq miles. Actually, there are nearly 100 separate systems or service zones in this area. Most of the city area, consisting of gently sloping valleys, coastal plains, and rolling foothills, is served by the larger gravity system service zones which still supply water for orchard and crop irrigation in areas of the San Fernando Valley not yet developed for other uses.

The city's principal water supply is from the Owens River Aqueduct, which enters Los Angeles through the foothills at the northern extremity of the San Fernando Valley at (approximately) el 1,460. From here, and proceeding south to the lowest system at the harbor in San Pedro (which has a reservoir at el 182), a network of major trunk lines distributes the supply through a series of pressure drops controlled by regulators and reservoirs.

The second largest source of supply, in terms of present annual use, is ground water from wells and collecting galleries. The most important of these are in the Los Angeles River and tributary basin area and are located in the southeast corner of the San Fernando

TABLE 1

Color Legend for 1,000-ft Scale Pipeline Maps

Item	Coloring Agent	Item	Coloring Agent
Pressure system boundary and elevation	Ink, brown	Reservoirs	
Proposed mains, 8-in. diameter and larger	Ink, carmine or pencil, red	Large, existing	Pencil, blue
Existing mains*		Large, proposed	Pencil, red
All trunk lines 16-in. diameter and larger	Ink, violet	Small, existing (and tanks)	Ink, blue
Cast iron, welded steel, and asbestos-cement, 12–14-in. diameter	Ink, green	Small, proposed (and tanks)	Ink, carmine
Cast iron, welded steel, and asbestos cement, 8–10-in. diameter	Ink, orange	Tentative tracts and extension numbers	Pencil‡
All small pipe, 6-in. diameter and smaller	No color	Unofficial tentative subdivision or study areas	Pencil, orange
Steel pipe, 12–14-in. diameter†	Pencil, green	Maximum and minimum recorded hydraulic grade and date (in circles)	Ink, carmine
Steel pipe, 8–10-in. diameter†	Pencil, orange	Pressure complaints (small square markers)	Pencil, red
Right of way for pipe obtained (small triangular markers)	Ink, black	Low pressure areas (outline)	Pencil, red
Pumping plants		High pressure areas (outline)	Pencil, blue
Existing	Ink, blue	Major street and bridge improvements	Pencil, gold
Proposed	Ink, carmine	Fire flow tests	
		Board of Fire Underwriters, 1935 Report (large triangular markers)	Ink, red
		Board of Fire Underwriters, 1947 Report (large triangular markers)	Ink, green
		Water system (circular markers)	Ink, red

* Dotted lines used when pipe on one system crosses area served by another system.
† Refers to old types of pipe—such as riveted steel—no longer installed.
‡ Distinguishing colors used to indicate fiscal year tracts were submitted or mains ordered.

Valley. The Los Angeles River was once the major source of the city's water supply.

The third major source of supply is the system of connections to the trunk lines of the Metropolitan Water District of Southern California. All of these connections are south of the San Fernando Valley and most of them are located along the east side of the city, running south to the harbor at San Pedro. Because the entire capacity of the first two sources is required to meet present demands, the supply required from the Metropolitan District connections is rapidly increasing, and is expected to provide for most of the city's future growth until, when necessary, another source is found. As a result of this growth, the Metropolitan District connections will be the second largest of the city's supply sources, in terms of annual use. In a very few years, in fact, as planned improvements are completed, this source will have the second largest total capacity or potential for emergency and peak load requirements.

There are some facts about the Los Angeles water system which are not

widely known. There are numerous foothill and mountain areas around the fringes of the major gravity system, and these must be served by booster pump systems. In the areas already served or provided for there are over 40 separate pump systems or service zones, each with its own pumping plant and tank (or reservoir). The larger of these have two or three pumping plants and two or three tanks or reservoirs each. In addition, there are nearly twenty small zones supplied from these larger systems by regulators. In all, there are almost 50 booster pumping stations, 40 tanks, and sixteen small reservoirs in these pump systems, and some of the pump stations contain two or three pump system plants in one building. The lowest pump supply system is at el 400, the highest at el 2,150. Another is planned in the Sunland-Tujunga area at el 2,440, which is about ½ mile above sea level and almost 1,000 ft above the highest gravity system in the city.

A considerable portion of the more rugged or remote mountain area within the city limits has not yet been developed or supplied with water. The largest of these unserved areas is located in the Santa Monica Mountains and approaches el 2,100 within 5 miles of the Pacific Ocean. Another large unserved area, in the northeast corner of the city near Tujunga, contains a mountain whose peak extends beyond el 5,000. Some of these unserved areas are very rugged and primitive, but the department has received occasional requests for estimates of the cost of furnishing water to future subdivisions in some parts of these areas.

Standard Color Legends

In most of the accompanying illustrations, the original drawings relied heavily upon color schemes and standard color legends. Unfortunately, the colors cannot be reproduced here, but, where possible, the color scheme has been described in the text. The use of color to bring out important features on maps and charts in both analysis and planning is very helpful, particularly when certain colors are reserved for specific purposes.

Table 1 shows the color legend used on the water system's 1,000-ft scale pipeline maps. At this scale it requires seventeen $3\times3\frac{1}{2}$-ft maps (now being replaced by 30 smaller maps of $2\times3\frac{1}{4}$ ft each) to cover the city area. There is too little space at this scale to show water main sizes by large, legible figures or by varied line weights without obliterating other desirable information. The color scheme for various pipe sizes allows the viewer to see the details as well as the whole pattern of system strength at a glance. The violet color indicates trunk lines of 16-in. diameter and larger; green indicates 12- or 14-in. mains; and orange indicates 8- or 10-in. mains. The lines showing mains of 6-in. diameter and less are not colored. A glance at such maps is sufficient to indicate the weak points of the system—such as areas in which no mains have yet been installed or where older, smaller mains have not yet been replaced. The same color scheme is generally used on other maps for special study and in reports, regardless of map scale. It has also been used (with minor variations required by the dark background) on a set of 1,000-ft scale aerial photographic maps for the northern half of the city. The benefits of these color schemes will best be illustrated if the reader applies the color legend in Table 1 to a copy of his own system maps or to the illustrations of this paper, as marked.

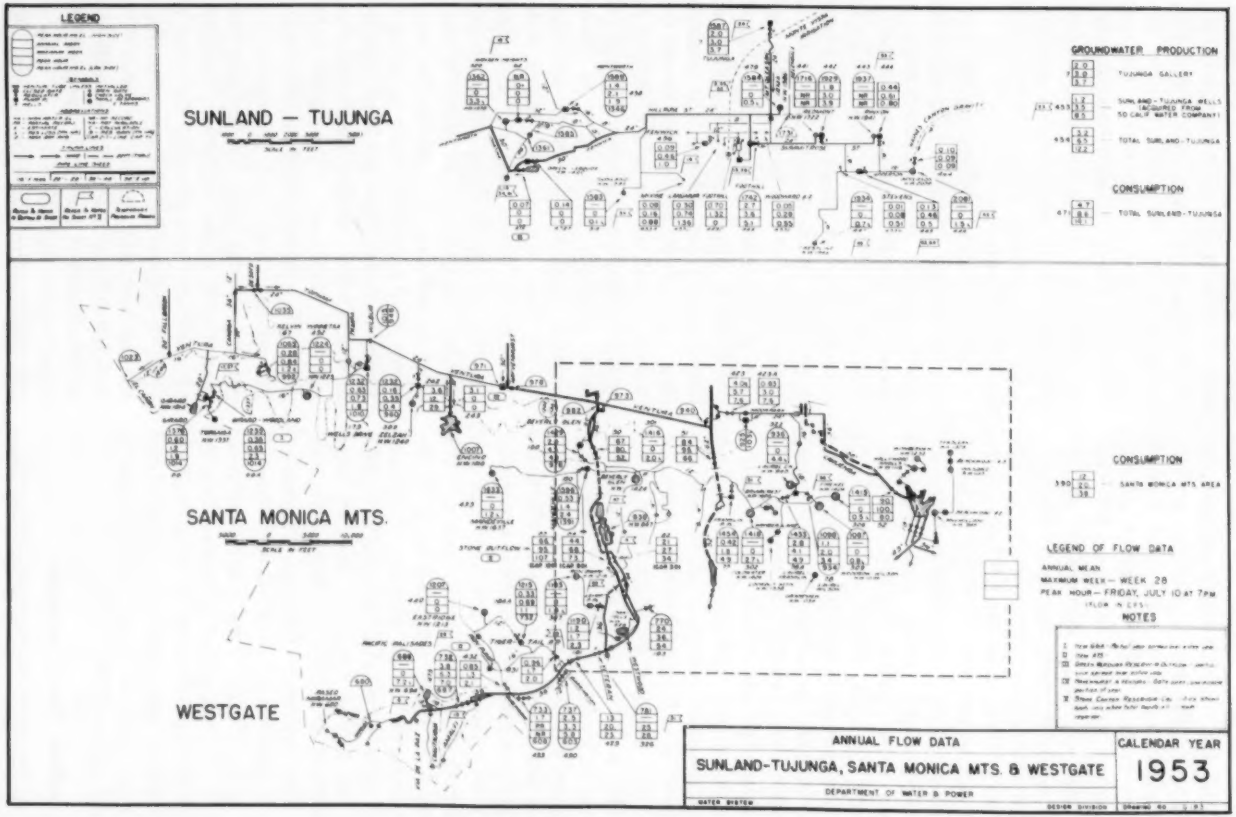


Fig. 1. Typical Annual Flow Data Sheet

Pressure and Flow Data

Permanent recorder stations. Figure 1 shows one of four annual flow data sheets prepared each year, showing data from the permanent pressure, water stage, and flow recorder stations throughout the city water system. This sheet covers the Sunland-Tujunga, Santa Monica Mountain, and Westgate areas, where most of the Los Angeles pump systems are located. The preparation and use of these flow data sheets have been described in detail in a paper by Charles J. Itter (*1*). Sheets similar to that shown in Fig. 1 are prepared for the other three major districts and show annual, maximum-week, and peak-hour flow; peak-hour hydraulic grades; water levels at reservoirs and tanks; storage in major reservoirs; total production and consumption for each district (as well as for the entire city); and rainfall, temperature, and other miscellaneous data. A similar set of weekly data sheets is prepared throughout the year, but peak-hour flow and hydraulic grades are shown only once a month, during the period October–June.

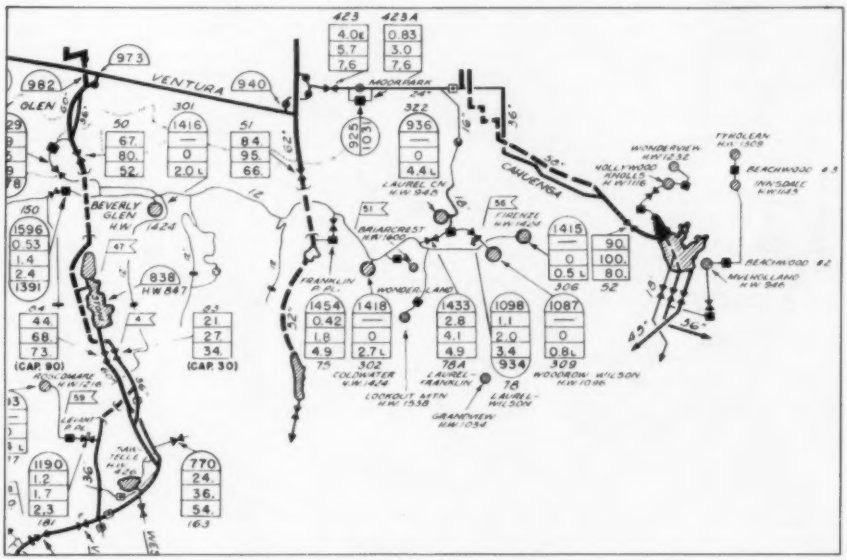


Fig. 2. Enlarged Detail of Annual Flow Data Sheet

Rectangles contain flow data (in cubic feet per second) with annual mean above, maximum week in the middle, and peak hour below. Circles or semicircles contain hydraulic grade data, with pump discharge above, suction below.

As shown in greater detail in Fig. 2, the rectangles contain the flow data (in cubic feet per second) with the annual mean on top, maximum week in the middle, and peak hour at the bottom. The circles or semicircles contain the hydraulic grade data, with the

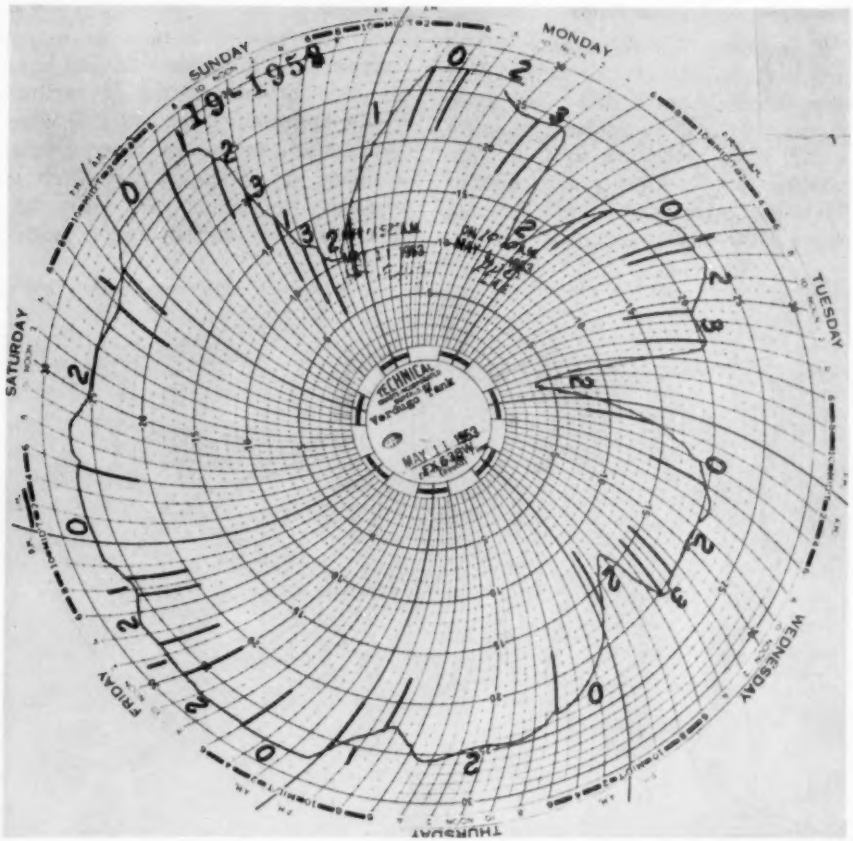


Fig. 3. Water Stage Charts, Verdugo and Highland Park Tank System

Chart shown is from one tank in a two-tank system supplied by a single three-unit pumping plant. Numerals indicate number of pumps in operation.

pump discharge on top and suction at the bottom. Most of the flow data of the smaller reservoirs and tanks are calculated from water stage records, and are shown in flow boxes, with *L* to indicate loss or *G* for gain.

The small numbered flags (usually colored purple for emphasis) refer to a tabulation of data on system operation on a fifth annual data sheet. When the circles are colored red, they indicate locations at which substandard pressure occurred. All new installations or removals of key facilities are listed annually together with the date of occurrence on the fifth sheet, which also includes the date of any major outages of pumps, tanks, or mains,

or other unusual operating conditions which might indicate a need for improvement. The four flow data sheets for the entire city contain over 500 items of data on flow, pressure, water stage, production, and consumption. Flow and hydraulic-grade data are entered on transparent copies of a master tracing in the boxes and circles provided thereon to facilitate comparison with past and future data sheets. Extra copies, complete with weekly or annual data, are then distributed to the various design, operating, and management personnel who need them. The department maintains almost 120 nonrecording flowmeters, 150 flow recorders, 120 pressure recorders, and over 50 water stage recorders at permanent stations, from which the information plotted on these data sheets is obtained.

Special or temporary recorder stations. In addition to the information from permanent recorders, as many as 250 special pressure surveys or flow tests are made each year throughout the city. About 30 of these are for detailed periodic analysis of the operation of an individual system. In such analyses, accurate flow and pressure data are essential. The other surveys provide information for the solution of local problems, such as fire flow test data or data on the adequacy of pressure after receipt of a complaint. Over 85 pressure recorders, ten water stage recorders, and three pitot-type flow recorders—all portable—are available for this work. A fourth type of portable recorder can be attached to the gear box of flowmeters which have only a totalizing indicator.

In most instances each of these special surveys or tests is taken for 1 or 2 weeks in the summer and includes from one to ten pressure recorders. Obviously, these surveys cannot all be scheduled for the same peak-demand period, but fire flow tests can sometimes be ordered for small systems or for local areas in large systems to simulate peak loads for a few minutes.

The data from nearby permanent pressure stations are of particular value when correlated with the special survey data. If the actual test period is not typical of peak demand, the records from permanent stations will indicate fairly closely in most cases how much the special records might have to be corrected to simulate the maximum-demand conditions recorded.

Accuracy of Records

For some purposes, such as checking local pressures, an error of from 2 psi in 40 to 5 psi in 100 will not involve safety of water works or customer equipment and will not be noticed by the customer. In such cases accuracy is therefore not important, and there is no need for extra-quality equipment or special care. In some other types of problems, however, it would be desirable to keep the errors in pressure and hydraulic grades to less than 0.5 psi regardless of total pressure. Good quality equipment and extra care are required to keep the error within 1 psi on a 200-psi recorder (or 0.5 per cent of the maximum recorder range). This is possible with ordinary commercial equipment when proper care is exercised.

Over a period of years the department has used a wide variety of flow and pressure recorders marketed by a number of manufacturers. Nearly all of these have been found reliable for general use under a program of periodic testing and adjustment. When a small difference in pressure between

adjacent stations is to be used to estimate flow, however, it must be recognized that these recorders are so delicate as to require more than ordinary care to maintain instrumental accuracy. The portable pressure recorders, in particular, are sometimes subject to rough treatment by the public, and particularly by adventurous juveniles. A well planned procedure for insuring instrumental accuracy and the elimination of human error is the first prerequisite for obtaining accurate data from both portable and permanent recorders. Another prerequisite is the provision of correct elevation data for all pressure recorders.

Fortunately, the office of the city engineer maintains a large network of benchmarks with accurate elevation data throughout the city. The Department of Water and Power has survey data to supplement this at most of its tanks, reservoirs, and pumps, so the elevations of permanent recorders can usually be determined very accurately at little expense. The city engineer's office also maintains an accurate set of 400-ft scale drainage maps and other records from which the top-of-curb elevation can be obtained at most points where a temporary pressure recorder would be installed.

The procedure required to obtain an instrumental accuracy of 0.5 per cent of the recorder range and to eliminate human error may seem too elementary to justify detailed comment. Experience, however, indicates that a large number of new employees, including experienced men and college graduates, obtain poor results because of a lack of information on this subject. Many assume that reading the data for several stations at a given hour on the charts will automatically provide the correct answer. Calculations based on such an approach occasionally indicate that water is flowing uphill; and the poor results frequently lead to the hasty conclusion that the equipment is unreliable. Actually, although a detailed account of desirable procedure may seem tedious, the corrective steps are easy and can be incorporated in a routine program. Close adherence to this procedure is essential to obtaining correct and accurate results from the system analysis methods described in this paper. The outline of procedure for eliminating or minimizing errors which is distributed to Los Angeles' water department employees has been included as an Appendix at the end of this paper.

Pressure Records

In the foregoing description of flow and pressure data the need for accuracy of pressure records for certain studies was emphasized, and the use of a larger number of pressure recorders than flow recorders was indicated, particularly for the special surveys in which portable recorders are used. Supply sources of all of the major and most of the minor distribution systems have permanent recorders which provide necessary information on inflow, outflow, and pressure or hydraulic grade at the sources. Water stage recorders not only supply the information on water level or hydraulic grade at tanks and reservoirs, but furnish data for computing storage (used or available) and for computing inflow and outflow from small tanks or reservoirs where the cost of inflow and outflow metering cannot be justified.

There are more pressure recorders than flow recorders at permanent trunk line junction stations in the system, and

almost all the portable recorders are pressure or water stage recorders. Very little measurement of flow in distribution mains has been found necessary.

The permanent pressure recorders and occasional portable recorders are used as trouble indicators. Where excessive pressure drops are indicated by these recorders or by customer complaints, portable pressure recorders are set at nearby key points for a special survey to locate system weaknesses, improperly shut gates, or pipeline obstructions. Unless the pressure recorders indicate low friction coefficients or some otherwise unaccountable situation, the flow in individual mains is considered for most system analysis and design purposes to be a "curiosity figure" which does not justify the expense of installing a flowmeter for either permanent or temporary records. The overall system or network capacity required to deliver the necessary quantity to a given location is usually much more important than the flow or capacity in individual mains. Fire hydrant flow tests provide an easy, inexpensive method of measuring large flows to a given point and of testing overall system capacity as well as local pressure drops in individual mains. The flow or discharge is measured by pitot tube as it leaves the fire hydrant without the need for expensive flowmeter installations in the mains. When unaccountable local pressure drops are indicated, additional pressure recorders can be used to bracket or spot the location of an obstruction or partially shut gate. If the pressure drop is uniform, however, and due to excessive friction losses, a flowmeter may occasionally be required to determine the friction coefficient.

System Analysis Methods

A system analysis usually involves the use of flow and pressure data from a large number and variety of charts taken from recorders at different elevations. The problem is to reduce this confusing mass of data to some compact form on a single graph, chart, map, or hydraulic-grade profile so that the nature of the system operation is clearly apparent, and any weakness or undesirable performance is easily discernible. The typical examples of analysis charts or graphs which accompany this paper require some explanation. To achieve a clear reproduction of these charts it was necessary to redraft them, using heavier lines, larger letters, and briefer notes than were used in the originals, and merely indicating the original colors used.

Figure 3 shows a water level or water stage chart for one of two tanks in a system supplied by a three-unit pumping plant. On these charts the pump operating time, derived from pump recorder charts, is usually indicated by a color legend. (No color indicates pumps are off, violet indicates that one unit is on, orange that two units are on, and green that three units are on.) For those who prefer not to use color legends, a numerical key can be inscribed around the margin, as shown in Fig. 3, to indicate the number of units operating. The purpose of this type of analysis is to determine if there is a consistent pattern or relationship between low or falling storage water levels and the number of pump units operating. If such is the case the pump starting switch is not consistently turning on the pump units soon enough to prevent

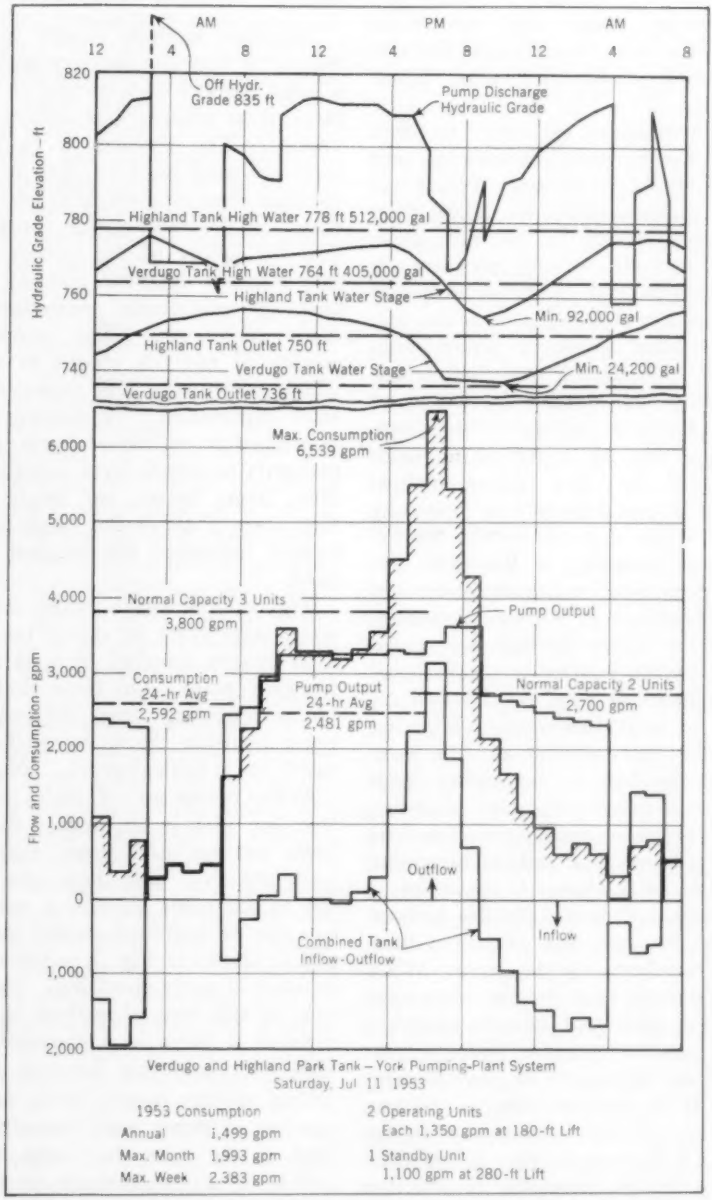


Fig. 4. Daily Hydrograph, Verdugo and Highland Park Tank System

a considerable unnecessary draft on tank storage.

In general, the pressure-operated pump switches are convenient, reliable, and accurate, but when discharge pressures are high, or the tank too far away, or the supply line friction losses appreciable, or some small or remote auxiliary tank in the system is difficult to keep full, then the pressure-type starting switch does not always function with sufficient accuracy. Further analysis of system operation is then required to determine the cause and the least expensive remedy.

Hydraulic-Grade Profiles

Profiles drawn to scale are usually prepared for principal supply line routes showing the ground line along the route, the highest ground elevations served from branch lines, and the system boundary elevation. On this base hydraulic-grade lines are plotted (in various colors) for night filling, maximum-day average, and peak hour flows. These profiles are ideal for locating line obstructions or excessive friction losses. However, when several sources are involved, particularly when tank elevations or regulator settings are not balanced, and irregular flow during the 24-hr cycle results, profiles at other hours may be required to truly represent system operation. The system must be visualized as a living, changing, four-dimensional problem, with two dimensions fixed on a map and some vertical dimensions fixed on a profile, but with hydraulic-grade dimensions constantly changing on the profile with time, the fourth dimension. For this purpose the daily hydrograph for small systems (or the annual hydrograph for certain large systems) must be studied to make sure that hydraulic-grade profiles are chosen and plotted for the correct hours of the day to tell the full story. These daily hydrographs can be visualized (after some practice) as end views of a whole series of hydraulic-grade profiles.

Daily Hydrographs

Hourly fluctuations for a 32-hr period have been plotted on Fig. 4 from actual recorder chart data to show pump discharge hydraulic grade, tank water levels, pump output, tank inflow and outflow, and total system consumption. Where pressure records are maintained at other points in the system and show valuable information, the data from these are also plotted. When the two tanks operate together, as was actually the case in Fig. 4, the combined inflow and outflow is shown; otherwise, separate inflow and outflow curves are plotted for each. The hourly fluctuations are plotted in color on prints of a basic tracing which already has scale, elevation, and capacity data plotted. All pressure data are plotted at the top of the chart as hydraulic grade in feet at USGS datum. (This is the standard datum used throughout the city by both the city engineer and the Department of Water and Power and by most other local agencies.) All flow data are plotted at the bottom of the chart, using a common zero base line. The standard colors for both hydraulic grade and flow at pumps and tanks are used on these charts.

When pump suction fluctuates or falls lower than planned, pump output is reduced below rated capacity, and suction hydraulic grade becomes an important factor in the analysis and should be shown on the chart.

There are several reasons for showing a 32-hr period. First, most people like to orient themselves to the 24-hr

period from midnight to midnight, but the actual consumption cycle runs from about 8 AM to 8 AM. This chart includes both periods. Second, it is desirable to know whether or not some fault in the previous night's operation caused the system to get off to a bad start at 8 AM, and whether after a heavy daytime load the system operated properly to recover full storage to meet the next daytime load at 8 AM. higher friction losses, as indicated by the pump shutoff at 3 AM the first morning, when the higher tank was full and the lower tank still half empty. The third unit also shut off at 9 PM, when both tanks were almost empty and pressure still low, and all units shut off again at 4 AM the next morning, when the lower tank was half empty again. The friction losses through the larger mains to the higher

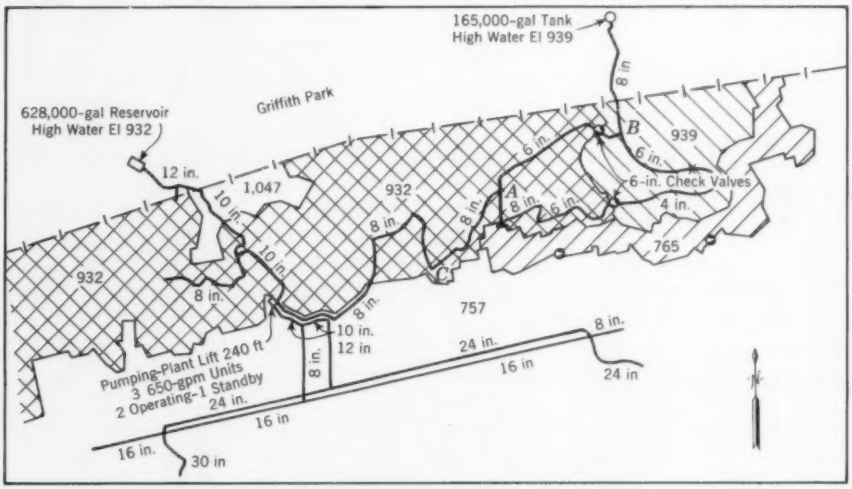


Fig. 5. Mead Reservoir and Griffith Tank System

The system shown is supplied by a three-unit pumping plant connected to a low-level reservoir and a small tank at slightly higher level. In practice, mains are colored according to color legend in Table 1.

The analysis in Fig. 4 is for the same two-tank system described in connection with Fig. 3 but covers a later date in the same year. The pump switches in this case functioned somewhat better than before, but tank water levels would have been maintained at a more desirable level if one pump unit had been kept on between 3 AM and 7 AM to fill the lower tank before the morning demand started to increase. This lower tank has a weaker supply line with tank are moderate. Improvement of the weak line to the lower tank would permit continued operation of more pump units long enough to fill the lower tank, and would keep it more nearly filled during the day.

In this and nearly all other cases, tank inflow is controlled by an altitude valve and outflow by a check valve. In all recent installations the altitude valve is hydraulically operated and is controlled by a float-operated pilot valve.

With a large check valve for outflow, the altitude valve need not and does not open immediately, and may not open for an hour or more after the tank is filled and the pumps shut off. During reverse flow with the pump shut off, friction losses in the line back to the pump create a lower pressure at the pump, which can quickly start the pump, if the switch is set high. With the altitude valve still shut, however, the resulting pressure surge is not desirable, particularly if the off-and-on cycle repeats itself rapidly. If the friction loss is high, the starting switch must be set quite low to avoid this surge, and under some conditions of lower consumption and lower friction loss before 8 AM the tank will be drained to a low level before the pumps are started. A larger supply line is an expensive remedy unless sufficient power savings result or other reasons exist for enlarging the line. An inexpensive time switch will start the pumps often enough during low tank outflow to maintain better pump output and higher water levels in the tank. As shown in Fig. 4, the water level does not drop fast in a 2–4-hr interval except when accompanied by a large tank outflow and large pressure drop at the pump, which would actuate a pressure starting switch in any event, even when set low. The time switch should therefore be connected so as to supplement the pressure starting switch, but not to replace it.

These charts also provide data and factors for general use in planning and designing new facilities or new systems. For instance, the date on the chart shows it is for a hot July day, and the normal maximum pump capacity for two operating units is just above the average 24-hr consumption. The factors expressing the ratio of maximum to average annual consumption as derived from this chart are as follows: maximum month, 1.33; maximum week, 1.59; maximum day, 1.73; and peak hour, 4.4. Other system analyses have indicated higher ratios, including one maximum-day factor of 4.0 for a system in which the major form of consumption was crop and orchard irrigation. Several peak-hour factors as high as 6–10 have been recorded for systems of medium size and smaller.

The area under the consumption curve and above the pump curve gives the regulating storage actually used, and that above the average-consumption line gives the regulating storage theoretically desired for continuous 24-hr pump output at the average consumption rate. From one-fourth to two-thirds of the maximum-day consumption is found to be desired for regulating storage in most pump systems; additional storage for emergencies and fire flow purposes depends on other factors.

Annual consumption (derived from pump output records) for various types of service areas is compared to acreage served to arrive at an annual duty or depth-of-water factor which can be used in estimating future annual use for new systems. These data are supplemented by meter book data for selected small areas of various types. The maximum consumption for single-family residential developments on 100 per cent usable land has been increasing since World War II. Formerly, a duty or depth of 1.8 ft per year was a good maximum, and 2.0 ft was used frequently in postwar system design. Recent studies, however, have indicated a figure as high as 2.8 ft for one mass-produced, medium-priced housing development in a hot, dry, inland valley

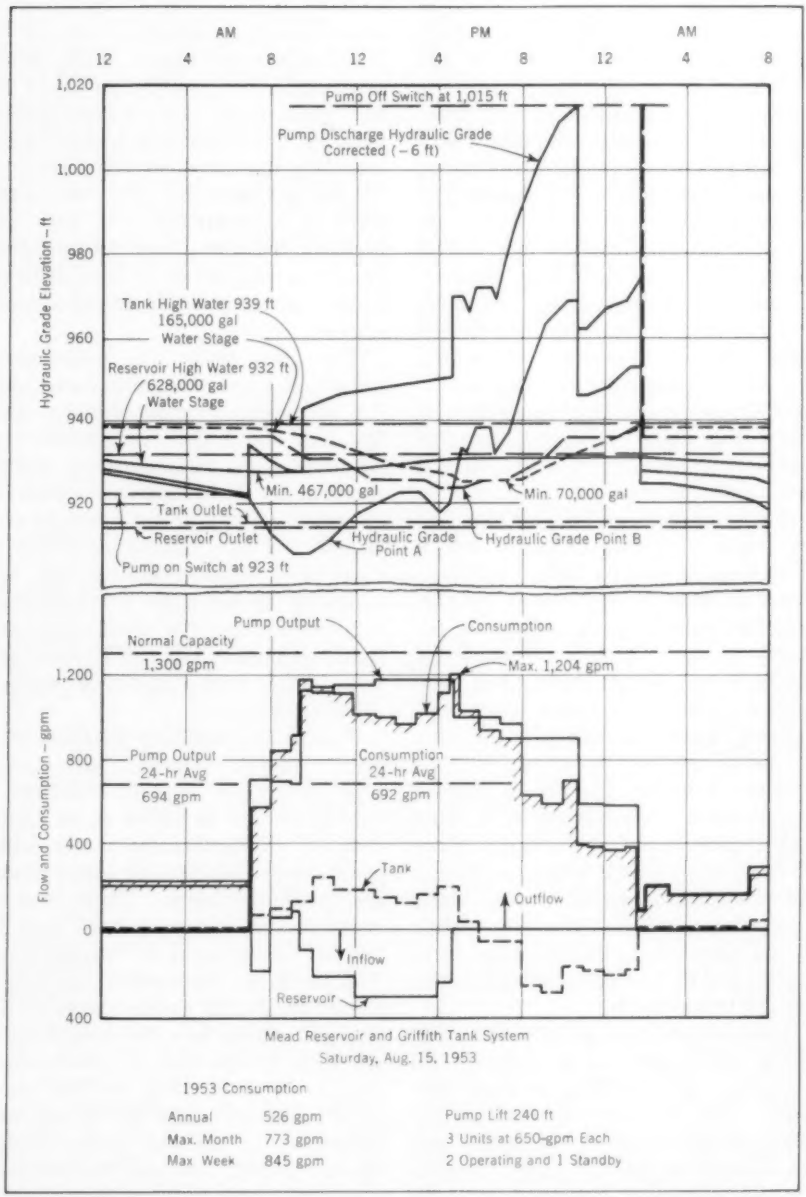


Fig. 6. Daily Hydrograph, Mead Reservoir and Griffith Tank System

area, with newly established lawns and considerable modern water-consuming household equipment. This area had an average of five dwellings per acre. Application of these figures to the design of proposed new hillside or mountain pump systems must be based on an estimate of the percentage of usable land which can be developed to use water at rates comparable to the average for flat or gently rolling hill areas. In some of the steep ridge and narrow canyon areas, the usable land area is only 10–20 per cent of the gross area, and the average duty on the gross area will be as low as 0.3 ft. Annual consumption estimates for new mountain area pump systems can seldom be based on population curves, since the service area constitutes a small new fringe area around the city, with no local past history or established nucleus of growth, and each area has many peculiar local characteristics, such as topography, which determine the possible rate or degree of development.

Figure 5 shows a map of another small system supplied by a three-unit pumping plant connected to a low-level reservoir on the west by a strong 10- and 12-in. main, and to a smaller higher-level tank on the east by a weaker 6- and 8-in. main. There are check valves in the 6-in. main and in another small parallel main to confine tank supply to a small area and prevent backflow draining the small tank when the pumps are off. A survey was ordered with pressure recorders at points *A* and *B* at each end of the 6-in. main to determine the cause of low water levels in the small tank. The system analysis is shown in Fig. 6, and includes hydraulic grades for points *A* and *B*. It might at first appear that the 6-in. bottleneck should be replaced with a larger main, but this analysis chart showed the check valve was closed from some time before midnight until about 4:30 PM, because the Point *A* grade on the pump side was below Point *B* grade on the tank side of the check valve. Replacing the 6-in. main with 12-in. pipe between points *A* and *B* near the check valve would not change the grades or open the check valve any sooner, and would not therefore prevent tank drawdown from midnight to 4:30 PM. Benefits would be limited to an appreciable pressure reduction at the pump during afternoon and night filling of the tank and to a slightly more rapid filling operation due to a slight increase in pump output. The key to the problem is that pump discharge grades before 4:30 PM are controlled by the strong line to the larger lower reservoir, so that they are not high enough to open the check valve and feed the tank through the weaker 6- and 8-in. line. The demand in the area east of the pump is causing a large flow and a large friction loss in the 8-in. line near the pump, which results in the low grade at Point *A*. At 4:30 PM the lower reservoir was filled and shut, and the pump output, which was then diverted to the 8-in. line, raised the grade at Point *A*, opened the check valve, and started flow into the tank after 4:30 PM.

The information derived from this hydrograph led to the adoption of another plan to parallel the existing 8-in. main with 12-in. line near the pump after it was found that the grade at Point *A* would be much higher after 7 AM than it had been during the pressure survey—in fact, that it would be above the tank water level and would open the check valve before noon. The tank water level and grades at Point *B* would be kept higher between noon and 4:30 PM because of earlier opening of the check valve. After 4:30 PM, the pressure reduction at the pump

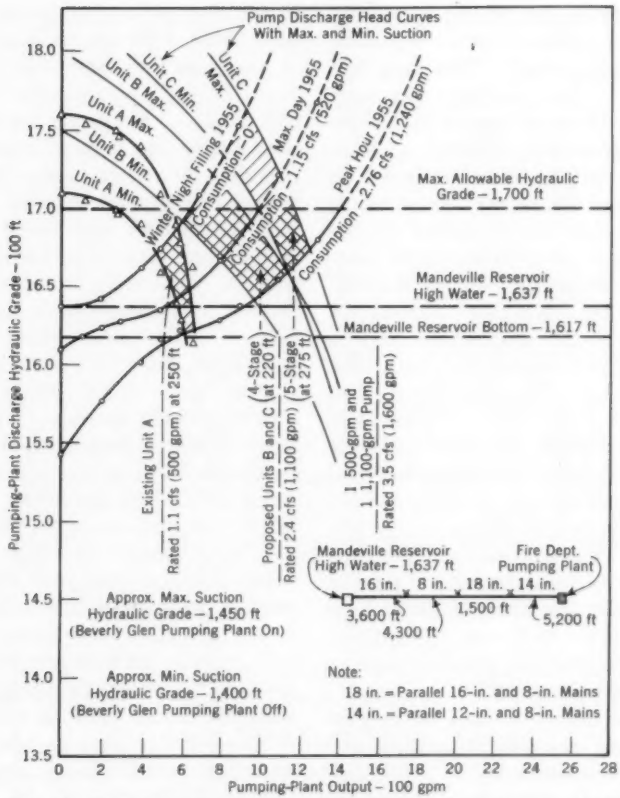


Fig. 7. Fire Department Pumping-Plant System Curves—1955

would be better than it would under the other plan (to replace the 6-in. main near the check valve), with slightly higher pump output filling the tank more rapidly. Because there would be less storage to be made up, a full tank and pump shutoff would occur much earlier, eliminating the last several hours of high-pressure pump operation.

After the 12-in. main is installed near the pump, there should be too little tank drawdown and too little high-pressure pump operation at night to justify further expense for enlargement of the 6-in. mains near the check valve.

Pump System Curves

In planning new systems or improvements of existing systems, it is desirable to represent all possible operating conditions at the pumps on a graph which can be used by the mechanical engineer as a guide in choosing the pump units for a new installation or in checking existing units.

The three graphs shown in Fig. 7, 8, and 9 were prepared in 1952 to represent conditions then anticipated for 1955, 1962, and the ultimate future, for a system which originally had a 500-gpm pump, 11,000 ft of 8-in. main, and no tank, and which had

originally been installed along a mountain-top road for fire protection purposes. A large hillside subdivision required the addition of a reservoir connected by 3,600 ft of 16-in. main to the end of the existing 8-in. pipe; it also required paralleling the 8-in. main with some 12- and 16-in. pipe. The capacity of these parallel mains is equivalent to 14- and 18-in. mains, as indicated on the schematic map at the lower right of Fig. 7. Since the progress of development of the area was uncertain, it was desirable to operate as long as possible with existing facilities and parallel as little 8-in. main as possible; hence, the charts were to indicate stages of anticipated growth and needed improvements.

The scales on this graph indicate pump output across the bottom and pump discharge hydraulic grade (USGS datum) up the left side. A 50-ft difference in pump suction grades is indicated by the notes at the lower left. The reservoir bottom and high water elevation, and the maximum allowable grade in the system are indicated by horizontal dotted lines above the center of the graph. The latter elevation fixes the shutoff switch setting, and was determined in this case by a desire to eliminate pressures in excess of 250 psi at the lower system boundary and to avoid excessive friction loss and pressure fluctuations in the system. As a result of the long line, the 63-ft friction head allowed above the reservoir elevation is higher than usual. The output head curve for the existing small pump is shown at the upper left for both maximum and minimum suction.

Against these background data there have been plotted three system curves representing hydraulic grades at the pump for various pump outputs, each curve being for a different rate of consumption anticipated in 1955. All three curves assume (for plotting purposes only) that pump output can be varied as required.

The upper winter night-filling curve assumes the reservoir to be almost full and consumption at zero. The middle curve, representing average maximum-day consumption between the reservoir and the pump, assumes the reservoir level to be down a third. The lower curve, representing peak-hour consumption between the reservoir and the pump, assumes the reservoir level to be down two-thirds. If all withdrawals were made beyond the reservoir, there would be only one system curve, the winter night–filling curve. These curves are somewhat similar to those described in a previous article by Leslie Paul (*2*). It should be understood, as described in the Paul paper, that there will be a pair of curves for each different rate of consumption to show the effect of a full or empty reservoir, and that there are actually an infinite number of parallel curves for various reservoir water levels within the limits defined by each pair of curves for a given rate of consumption. There are also an infinite number of pairs of curves for various other rates of consumption. For simplification, the full range in normal pump-operating conditions is indicated by the highest curve for winter night filling with a full reservoir and the lowest curve for the peak hour with a low reservoir stage. The middle curve for the maximum day at the average reservoir stage provides a guide to an average normal operating condition and assists in interpolating curves for other rates of consumption when such information is needed. Such interpolation is usually accurate enough when the curves are

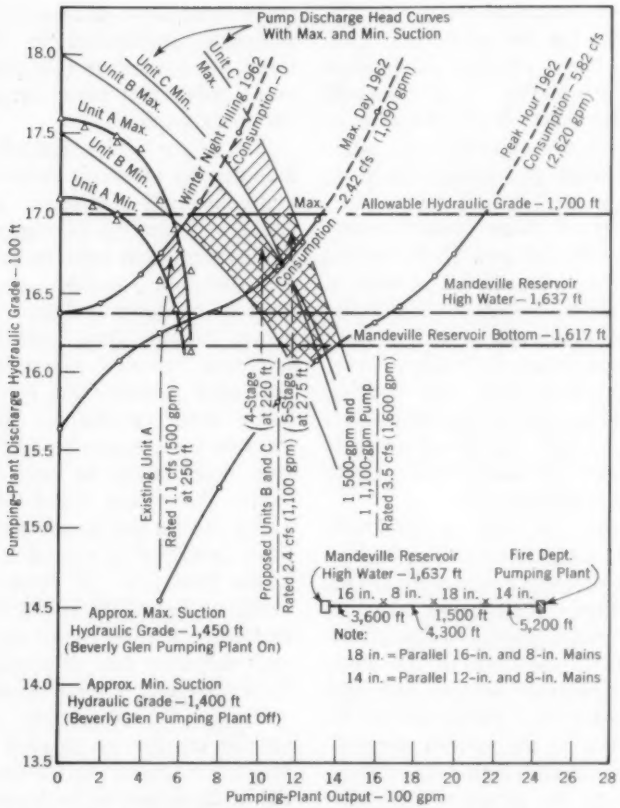


Fig. 8. Fire Department Pumping-Plant System Curves—1962

close together. For operation at other reservoir levels than assumed for these curves a simple correction for the difference in water level will suffice.

For zero pump output the system is supplied by the reservoir alone, and the hydraulic grade at the pump varies accordingly. The system is static for zero consumption and zero pump output assumed for the winter night-filling curve, and the pump grade equals the reservoir water level. For all other rates of consumption with the pumps off, the pump grade must be below the reservoir, and will remain below the reservoir (as indicated by the left portion of the two lower curves) as long as pump output is small compared to the consumption withdrawals. Once the typical shape of these curves is understood, it is usually sufficient to compute two to four points on each, particularly if the points are plotted near the anticipated location of the intersections with the pump curves.

Figure 8 is for the same system of mains but with a larger consumption predicted for 1962. The winter night-filling curve is therefore identical with

1955, while the other two curves indicate lower pressures due to larger consumption. The curves for both 1955 and 1962 are all steep, because of the 4,300 ft of 8-in. mains assumed not yet paralleled.

Figure 9 is for an improved system of mains with all of the 8-in. mains paralleled by 12- and 16-in. lines for ultimate future consumption. The curves are flatter because of the larger mains.

These system curve graphs assist in pump selection when actual or proposed pump output head curves are plotted, as shown in these same three graphs, Figs. 7, 8, and 9. Two 1,100-gpm units of a three-unit plant have already been installed, and the actual curves for these units are shown plotted on the system curve graph for 1955 (Fig. 7), together with the curve for the original 500-gpm unit, which is still in use. One stage of one of the new five-stage units was temporarily removed to reduce discharge head and capacity in order to avoid higher pressures at night until the system could be strengthened to reduce friction losses.

Where a range in suction grade occurs, two pump curves are drawn for each unit or combination of units, one for maximum and one for minimum suction. There will be an infinite number of parallel pump curves between these limits, one for each suction grade. The normal pump-operating range is defined by the intersection of these maximum and minimum pump curves with the maximum and minimum system curves, and is indicated by the cross-hatched area for each unit or combination of units. The single-hatched area indicates operating range eliminated by the shutoff switch. The use of the five-stage unit would be limited to standby or peak consumption periods in 1955, and combined use of two or more units would not be possible if the 8-in. main were not paralleled.

Figure 8 indicates a wider fluctuation in operating range and less desirable lower pressures associated with the expected higher consumption in 1962. The five-stage unit could be used more often with higher consumption rates in 1962, but combined use of two units would be possible only at peak hour if the 8-in. main were not paralleled.

Figure 9 for the ultimate future assumes the 500-gpm unit to be removed, and the three 1,100-gpm five-stage units installed (two in operation and one as standby). The operation of two units for winter night filling with zero withdrawals is eliminated by the shutoff switch, but since actual night filling at other times of the year involves small withdrawals and a lower curve, two units can be used whenever they are needed.

One of the typical difficulties in system planning in mountain areas was encountered in the system shown on these charts. Between the date on which these curves were drawn and the system planned (in 1952), and the same date two years later, one subdivider near the pump developed a sizable area much sooner than anticipated by using heavy grading equipment and leveling off the tops of ridges, filling valleys, and then mass-producing homes on most of the lots in the subdivision. Two other sizable areas outside the system boundary are also being supplied temporarily from this system.

The size of the consumption load and its concentration near the pump resulted in much lower system curves than anticipated for 1955 and greater use of the larger pump units, with cor-

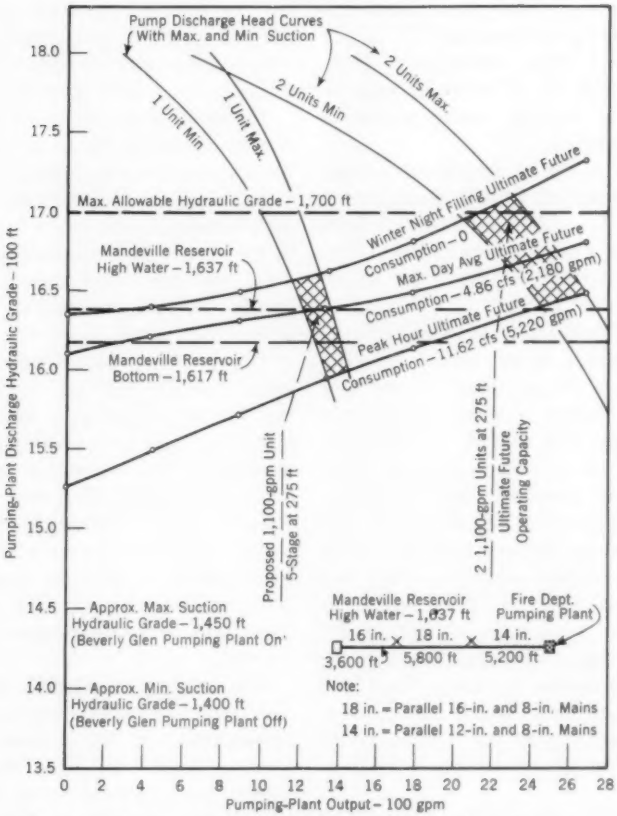


Fig. 9. Fire Department Pumping-Plant System Curves—Ultimate Future

responding undesirable pressure fluctuations. At present, the supply main improvements anticipated between 1955 and 1962 have already been installed, and the third large pump unit will be required in a few years. The rate of development of the remaining area remains unpredictable because of the variety of methods which the owners may choose to develop the property.

Figure 10 illustrates a similar set of system curves and pump curves for the actual 1954 operation of the Mead Pumping Plant. This is the same system with large reservoir and small, high tank previously described in connection with system analysis charts (*see* Fig. 5 and 6). In Fig. 10, the three lower system curves and the cross-hatched areas are for one, two, and three pump units in operation with the reservoir in service and the higher tank assumed out of service (with respect to the pump) because of the shut check valves in the 6-in. mains. The two upper system curves and the single hatched are for one, two and three pump units in operation with

the higher tank assumed in service and the reservoir out of service because of the shut altitude valve at the reservoir. During any one maximum day the reservoir can be out of service at certain hours when it is full and the altitude valves shut, and the tank can be out of service (with respect to the pump) when the reservoir is only part full and lower pressures cause the check valves in the lines to the tank only for a moment when the system consumption equals the maximum-day rate of 2.0 cfs at about 8 AM, and is not the usual average of all operations for the maximum day. In this instance the latter would be a combination or average of two distinct and separate operations, rather meaningless and difficult to compute.

The difference between system curves for a weak supply main and a strong

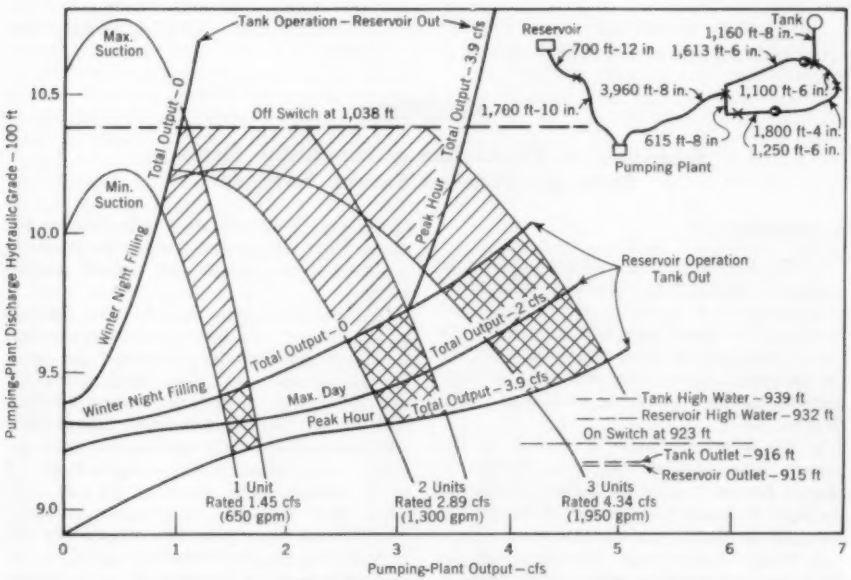


Fig. 10. Mead Pumping-Plant System Curves, 1954 Operation

to be shut. Simultaneous operation of both the tank and the reservoir is usually impossible with the present mains and check valves and peak-hour demand with the reservoir out of service is improbable. Interpolation for combined operation of reservoir and tank therefore cannot be made in the usual manner at random over the operating range indicated. For instance, in this case the maximum-day curve shown with the tank out of service is one is quite clearly indicated on this graph. Any improvement of the 6- and 8-in. mains between the pump and the small tank would flatten the steep system curves, but with the pump-to-tank distance almost three times as great as the pump-to-reservoir distance, it would take a larger main than 12 in. for the entire distance to bring the curves close together for perfect balance. This idealistic solution is unnecessary and far too expensive. The

correct solution is to provide only enough 12-in. line at the best location for reducing excessive friction losses and shortening the length of time that the tank is separated from the pump and reservoir by the shut check valves so that storage withdrawal from the tank is kept within safe limits and filling the tank is made easier and more rapid.

Acknowledgment

The author is indebted to his associates and supervisors in his own and other divisions of the Department of Water and Power of the City of Los Angeles for their advice and assistance in developing the methods of analysis and planning here described as well as in the preparation of this paper.

References

1. ITTER, CHARLES J. Los Angeles Distribution System Flow Analysis Methods. *Jour. AWWA*, **37**:379 (Apr. 1945).
2. PAUL, LESLIE. Remote Pump and Valve Controls. *Jour. AWWA*, **45**:121 (Feb. 1953).

APPENDIX

Procedure for Eliminating or Minimizing Errors in Flow and Pressure Survey Analysis

A. Planning

1. The list of recorder locations must be carefully prepared to eliminate misleading descriptions and resulting errors in actual location. In many cases two mountain area streets intersect at more than one point, so the particular intersection and point of connection desired must be indicated very clearly.

2. The location should be written on the correct type of chart for the instrument chosen for each location before placing in the field to avoid possible use of the wrong recorder or the wrong chart.

3. Where lower-range recorders can be used, the degree of accuracy of the results will be increased; therefore, the planning list should include the range of flow or pressures anticipated at each location to facilitate the best choice of recorder.

4. A program of establishing fewer types and ranges of recorders as standard helps to minimize the use of the wrong charts. A larger variety of recorders requires a larger stock of charts, and the wrong chart is more likely to be used. (The wrong chart sometimes must be used if one unusual type is temporarily out of stock, in which case the fact should be noted on the chart.)

5. In standardization, preference should be accorded charts on which the unit of measure is indicated on the face, and charts for which special multiplying factors are unnecessary. Many charts simply indicate the range from one to ten and invite errors in decimal points or in the use of special factors.

6. Standardization should also include avoidance of multipen recorders, unless these are particularly convenient for some special purpose—and then only when the operating range of each pen seldom conflicts with the others. An unreadable mess results when operating ranges coincide or cross too often. In addition, a time correction of 1–3 hr is automatically required for all pens other than the one set correctly on time. The size of the correction depends on the clearance space provided or required by the particular make of recorder in order to permit the pens to pass each other.

7. Standardization should provide for only one direction of rotation of the clock. Most rectangular charts read left to right and most circular charts clockwise, or left to right, at the top. However, a few record in the opposite direction, and considerable confusion results when it is necessary to correlate data from both types at the same time. The possibility of both mistaken time settings and mistaken time readings is considerably increased.

B. Field Work

1. In some areas it is necessary to clamp the box containing the portable recorders to fire hydrants, utility poles, or other solid

objects (subject to local laws) to avoid damage by irresponsible persons. In all cases the box or container should be locked.

2. Both permanent and portable recorders should be given a final test and calibration in place in the field in order to eliminate inaccuracy caused by the effects of handling. This test should be followed by a program of periodic tests for permanent recorders and for temporary recorders installed for long periods.

3. It is more desirable and useful to adjust for accuracy at the actual operating range anticipated than for average accuracy over the entire range of the chart. The latter method can result in small errors in the actual operating range due to minor defects in the mechanism or in the printing of the chart. Readings outside the normal operating range seldom, if ever, occur, and accuracy of such readings is obviously of little value. It is also very useful to have the test pattern and the adjusted pattern recorded on the chart actually in use at the time, so that personnel later analyzing the record can determine whether it is necessary to correct a previous record and if correction at an unusual operating range is indicated. This procedure also establishes the fact that a test and an adjustment were made and the approximate time this was done. The pattern seldom interferes with the record.

4. In using the dead-weight tester on pressure recorders only one standard elevation position should be used. This may be the center of the chart, the base of the recorder, or the curb or floor elevation. In any case the recorder is recording the pressure at the elevation of the testing machine, and the elevation of the testing machine must be known in order to compute hydraulic grades. Testing in the shop on a work bench ordinarily involves having the testing machine at or near the chart elevation, and placing the recorder in the field in an elevated housing ordinarily involves having the testing machine on the curb or ground at several feet less elevation. Obviously, the position used should be a matter of standard procedure and understood by all. The department uses the chart center elevation, both in the shop and in the field, and uses an adjustable table in the field to hold the testing apparatus at the correct elevation.

5. The pen arm center should be adjusted so that the pen arm arc conforms to the curved hour lines on the chart in order to avoid time errors which will otherwise occur during wide fluctuations in operating range, particularly with regulator station and pumping plant flowmeters. Some models of recorders have similar ranges and calibrations on the charts but do not have the same pen center or radius.

6. The speed of mechanically driven clocks should be checked and adjusted to avoid time gain or loss in excess of 15 min per week, particularly where large flow and pressure fluctuations may occur in a short time. Occasional time errors with electric clocks due to power outage are unavoidable, but these are quite evident from the record of time lost at the end of the week, and should be noted when they are known to have occurred.

7. The hour space on some weekly charts is so small, particularly at the center of circular charts, that time errors while setting the chart are unavoidable when the operating range is near zero. This is a good reason for using a low-range recorder and for setting the high-range pen on multipen recorders at the correct time.

8. As a means of providing for future checking and correcting of such time errors, the person placing the charts on the recorders should carry an accurate watch and note the date, day of the week, and exact time of setting the chart in place and taking it off, and initial same to fix responsibility. The usual error in setting a weekly chart on time involves less than 15 min. Sometimes, due to the narrow hour space (as small as $\frac{1}{32}$ in. on some charts), the error can be an hour or more. Occasionally, the optical illusion created by the curved hour lines can result in a 12- or 24-hr error, particularly when the actual operating range is near zero on the chart.

9. Absence of record can result from failure to wind the clock, failure to put the pen down on the chart, failure to tighten the set-screw which locks the chart to the clock hub, or failure to provide enough ink in the pen to last out the week. Some recorder locations are subject to more extreme or frequent pressure variations than others, and consequently use more ink. In extreme cases, these surges can cause the ink to collect in one spot and then run all over the chart. In order to obtain a usable record, some form of surge suppressor must be used which will not cause too much time delay but which will iron out most of the surges.

10. In a large organization the work is divided up into various steps which are performed by different individuals. As a large number of surveys are made in the summer

and the analysis of a particular chart may not be made until several weeks or months later, the field workers should enter on the chart any pertinent information regarding tests, adjustments, gates open or shut, or other special conditions or procedures, for the benefit of the person who analyzes the results. This eliminates the possibility that special operation data will be forgotten when needed at a later date. The principal duty of the field worker is to realize the possible errors in records and possible uses of the records obtained and follow a procedure which will avoid most errors and leave a clear record for the person who must analyze the results.

C. Analysis of Records

1. The first duty of the analyst is to recognize the possibility of errors in planning, field work, and analysis, and to follow the checking and correcting procedures necessary to find and correct them.

2. The first step to be taken before reading any data from any chart is to check the on and off times noted by the field worker against the actual pen record and make any time corrections necessary. If the error in time is the same at the on and off positions, the error should be constant throughout the chart, but if time has been gained or lost, the error may have to be prorated. The entire chart should be checked for any note or indication that the clock was reset for time during the week. More accurate time checks are noted in paragraphs below. For flow and friction head loss computation purposes, the objective is not the precise true time but rather the relatively correct time between readings taken from various charts in order to avoid mistakes in reading one chart before a change in operation and another chart afterward, or at a different time when a different flow or pressure occurred.

3. The second step is to check the calibration test charts to see if corrections of previous or subsequent records are indicated. As noted in Paragraph 3, under Field Work, small corrections at certain ranges may still be required after the recorder has been tested and corrected.

4. In most systems, particularly small local pump systems, there will be some period during the night when the pumps are off, consumption and flow in mains are almost zero, and the system is almost static. The hydraulic grade at all water stage and pressure recorders should be computed for this time and checked. If all recorder calibrations and all recorder elevations are correct and the correct charts have been used, then all hydraulic grades will be the same or nearly so. Since all flow under these circumstances is from the tank or reservoir, no other station should have hydraulic grades higher than the tank or reservoir. Where the flows are not too large, a rough calculation will indicate the proper friction loss and correct hydraulic grade at most stations, and the correction for all other hours at each station can be easily computed. In other systems where night flows are larger, plotting the hydraulic grade profile to scale for low flows indicates which recorders are in error, but the correction may not be as easily or as accurately determined.

5. Time checks can be made in several ways. Generally, the most reliable and rapid way is to spot a time when a sudden change in flow or pressure throughout the system is indicated, such as a pump turned on or off. On water stage recorder charts a sudden change in flow is indicated by an angle point or change in slope rather than a sudden change in water level. Check the hour on which most charts agree and assume this hour to be correct. All other charts not in agreement should be marked as incorrect and the necessary corrections made.

6. In order to avoid mistakes in reading, where time corrections are required for a number of readings in one day, put a mark on the chart and label the correct position for each of the hour lines with respect to the check point before taking off flow and pressure data.

7. Another type of time check-point is the peak-hour flow and pressure. When the peak is very pronounced, it has usually been found to occur simultaneously on all charts in the system.

8. When no common check-point for time correction can be found, the only procedure to follow is that noted in Paragraph 2 above, in which the on and off times are checked against the actual pen record.

9. Pitot meters and most other flowmeters in large pipelines will not record low flows indicated by small pressure differentials; thus, a zero flow may be indicated on the chart when there is actually small flow. On certain kinds of flow recorders, however, the chart will indicate a low flow when the flow is actually zero. This is due to a slight friction in the recording mechanism which prevents the pen returning to zero. A thorough knowledge of meter and recorder

characteristics and system operating characteristics is required to judge which type of error may be involved in a particular case.

10. In correlating results from a number of records on an analysis sheet or graph, it is ordinarily desirable to plot pressure data and flow data points only on the hour lines. However, where tank inflow and outflow must be calculated from water stage records as an average quantity between hour lines, all flow and consumption is best plotted in the same manner. Where sudden large changes in flow and pressure occur between hour lines, however, it is usually desirable to show the averages for the portions of the hour before and after the change, and thus indicate the true time and degree of sudden change (including unusual surges) on both the pressure and the flow portions of the analysis sheet.

Directors Oppose Return of Used Water to Mains

For many years this Association has been recognized as cooperating fully with state sanitary engineers and public health officials by opposing the existence of cross connections to the water distribution system and further by opposing the return of water that has been used for any purpose in the customers' premises to the service lines and mains from which it was taken. Since the beginning of use of water for cooling air-conditioning equipment, requests have been made more or less frequently to permit the return of water to the distribution system for general use after passing through an air-conditioning unit.

A review of the attitude of state sanitary engineers made early in 1956 indicated that all who replied to the inquiry opposed any deviation from the existing practice of "no return to the mains." The matter was again considered at the meeting of the AWWA Board of Directors held in connection with the St. Louis Convention on May 11. The following statement was approved by the Board:

> It has been the policy of this Association to oppose the cross connection of public water supplies with other supplies of uncertain nature originating on the premises of a customer. It has also been the general practice within the water works industry to reject any request for use of water from the public water supply system within the customer's premises for cooling purposes and its later return to the distribution system of the water utility. The Officers and Directors of the American Water Works Association hereby reaffirm the position previously taken that customers' use of water from the public supply system for cooling purposes on the customers' premises and later return of the used water to the distribution system of the water utility is not an acceptable or safe practice. The use of water conservation devices in connection with cooling equipment on customers' premises has been shown to be fully practical. Therefore, the return of used water to the distribution mains cannot be approved.

HARRY E. JORDAN
Secretary

Fire Protection Problems With Undersized Mains

Harry L. Krieger

A paper presented on Sep. 22, 1955, at the Ohio Section Meeting, Columbus, Ohio, by Harry L. Krieger, Asst. Mgr., Ohio Inspection Bureau, Columbus, Ohio.

THE fire protection problems involved in undersized mains should be of interest to designing engineers, water works officials, fire protection engineers, and health authorities alike. For many years, the fire protection efforts of the Ohio Inspection Bureau have repeatedly been concerned with the problem of 4-in. pipe. During depression years a large number of water systems were established in Ohio with assistance from the federal government. Plans were submitted to the bureau at that time—as, for that matter, they continue to be—involving so much 4-in. pipe that the systems described could not be considered satisfactory for the usual water works accreditation. In most cases, redesign of the main parts of the distribution system was required, so that at least the buldings of major value would have the protection needed. In some cases, in fact, the system had to be dropped from consideration, for frequently the town involved could not afford the necessary extra expense.

This discussion will not consider 4-in. mains exclusively, but rather will attempt to deal with the problem of undersized mains in general—whether 4 in., 6 in., 8 in., 10 in., or any other size.

It is to the average small water system that 4-in. pipe probably presents the greatest problem. In the typical small water system, such as would be installed in a town with a population of 500, the highly developed mercantile area is of such extent that it is desirable to have a momentary flow of 1,500–2,000 gpm. To obtain this for any duration it is necessary to have not only adequate main capacity but also adequate elevated-tank capacity. The pumps in a community of such size are usually small—possibly of 100-gpm capacity each. Most often the pumps discharge directly from the wells or a small-capacity treatment plant to the distribution system. Thus, it is necessary that fire flows come primarily from the elevated tank, and often through only a single line. A tank line of 8 in. in diameter or larger is required in almost all instances, and this should lead to a 6-in. loop circulating through the mercantile district, or the central area, depending upon the nature of the occupancy of the buildings.

It is in the territory beyond this central area that the temptation to use 4-in. pipe is greatest. In a small town, a 4-in. circulating grid, when not more than a block distant from larger pipe, can produce a satisfactory supply for a residential area; where the area may become a business district, however, or where churches or schools or other nonresidential occupancies are inter-

spersed among the dwellings, pipe of 6 in. or larger should be used. In rare cases where static pressures are fairly high and the supply is from a pipe of 6 in. or larger, a very short dead end of 4-in. pipe will produce a fair supply for a dwelling fire. A dead end of 4-in. pipe should be used, however, only where there is no likelihood of a change in the type of occupancy of the area and when it would not be physically possible to extend the line to serve other properties.

Hydrant Leads

A discussion of the problems connected with 4-in. pipe would not be complete without some study of hydrant leads (that is, connections from the mains to the hydrant bases). In general, hydrant leads should be no smaller than 6 in. even though connected to a 4-in. circulating main, for it requires the capacity of a 6-in. connection to utilize fully the water coming from both directions through a 4-in. main. On a 4-in. dead-end main there is nothing to be gained by making the hydrant lead of 6-in. pipe unless there is a chance that the dead end will be converted to a circulating main at some future date. It is obvious that the supply from any 4-in. dead end will be no better than fair and that a larger lead is not likely to improve the situation appreciably.

The recommendations made thus far apply exclusively to the very small community in process of installing its first water system. It should be noted that though these recommendations deal with the essentials of such a system, they would nevertheless be a bare minimum for acceptance by the inspection bureau. This discussion, however, would be of little value if it did not also include the author's recommendations for the best system over a period of years. When water mains are laid, the basis of the distribution system for the next 100 years is very often established. For this reason, it is not economically sound to consider only the immediate demand upon the mains.

Even though a community is zoned according to the type of occupancy or the height and area of the buildings, there is no assurance that this zoning will remain unchanged indefinitely; indeed, cases of residentially zoned areas being changed to mercantile or manufacturing areas are quite common.

A study of conditions in American cities, based upon fire flow tests conducted by the NBFU during the past 40 years, has shown that most often cities grow slowly, first in one direction and then in another, so that there sometimes exists extensive undeveloped area between a new development and the older section. There are, of course, a number of well-known cities whose growth has been extremely rapid in the past 10 years; for the most part, however, the generalization is true. Even in such cities as Gary, Ind., where more or less definite plans could be established before the city was occupied, it was not possible to control later development, with the result that there exist today extensive areas without a complete gridiron.

In spite of the widespread use in the past of 4-in. and 6-in. pipe for gridiron purposes, the present tendency in some cities—and this practice is recommended—is to use no pipe of less than 8 in. in any new development. With an 8-in. pipe a flow of 1,000 gpm can be obtained at the end of a 2,000-ft dead end with a loss of only 25 psi, and where pressures are high a satisfactory fire flow can be obtained at the end of a 5,000-ft dead end of 8-in. pipe.

Hydrant Distribution

For fire protection in a residential area there should be a distribution of hydrants in a ratio of one for each 120,000 sq ft of area. To supply these hydrants properly, the maximum area to be served by the pipelines feeding them is roughly equal to a 600-ft square, with a hydrant at each of the four corners and another on each side. On this basis, a gridiron of pipes of not less than 6 in. diameter and of a length between connections not exceeding 600 ft would normally be satisfactory for the average residential area. The interior pipelines could be of the same size, or even smaller, as they would be needed only for domestic consumption. These recommendations are based on the assumption that normal water pressures would be about 60 psi and could be maintained under sprinkling loads. To make such an arrangement effective there must be a well-planned system of primary and secondary feeders, providing pipe of 12 in. diameter or larger in squares approximately ½ mile to the side.

Developments along the edges of a distribution system or requiring extensions beyond the existing mains cannot be expected to include this arrangement of secondary loops of 12-in. pipe adequately supplied by feeder mains, nor will they consist of complete loops of 6-in. pipe, not exceeding 600 ft square. It is therefore a matter both of wisdom and of economy to use 8-in. pipe for all lines supplying hydrants in residential areas, and 12-in. pipe for all additional distribution lines in mercantile and manufacturing sections.

Recommendations

On the above basis, the NBFU recommends that the following be adopted as the standard minimum size of mains used for hydrant supply for all future construction:

1. For residential districts, 8 in.; 6-in. pipe to be used only where it completes a good gridiron and in no case in blocks 600 ft or more in length.

2. For mercantile and manufacturing districts, 8 in. and 12 in.; the former to be used only in sections where it completes a good gridiron, and the latter for long lines not cross-connected.

This recommendation is not intended to suggest that every street must be provided with an 8-in. or a 12-in. water main. Using such a recommendation as a basis for mains which will provide proper hydrant distribution of one to each 120,000 sq ft of residential area and to each 80,000 sq ft of mercantile and manufacturing area, it is evident that many long dead ends or extensive loops can be used making adequate fire flow available. Suitable domestic supply can be obtained with small lines: many systems are using 2-in. or 4-in. pipe for these domestic feeds.

Through the adoption of 8-in. pipe as the minimum supply line to hydrants, the city of Seattle, Wash., has developed a strong gridiron even though some dead ends in the city system are 2,500 ft long and other lines are in loops of 4,500 ft. Of the total pipe supplying hydrants, 65 per cent is of 8 in. size. Many other cities have adopted 8 in. as the minimum size: since 1916 the percentage of 8-in. pipe in the system supplying the District of Columbia, for example, has increased from 25 to more than 44 per cent.

As previously observed, these recommendations would provide a minimal basis for acceptance from a fire protection standpoint. The remainder of this discussion will deal with recommendations for a system which would

be graded or classified as exceptionally good. With regard to grading qualifications, it should be kept in mind that the grading of a city depends in large measure on the ability of the water system to deliver adequate fire flows. The size or adequacy of the fire department alone will not be sufficient to produce a favorable fire insurance rating. Most towns will be able to design and build a water system somewhere between the two extremes presented here —that is, between the merely acceptable and the exceptionally good—but, wherever possible, the features of the recommended grid should be adopted.

Undersized mains are frequently found in older cities, chiefly in the outlying areas; yet that is precisely where the majority of large new plants and shopping centers are being built. If an adequate water supply is to be obtained to protect values of this nature, new feeder lines must very often be extended from the water plant or elevated storage. Sometimes the task is impossible because of the great expense of laying such an amount of pipe. In such instances, increased insurance costs must be absorbed by the property owners. Many new plants constructed in outlying areas desire automatic sprinkler systems; in such event, when an adequate supply of city water is not available, a private tank must be erected. Often there is not even sufficient public water available for ordinary street firefighting. Overbuilding a water system is very rare; underbuilding and underdesigning are quite common. Many fire protection problems can be worked out in advance if only the proper people are brought together.

There is another type of undersized main which deserves mention at this point. Ten years ago, let it be assumed, a 12-in. line was installed to extend water service to a growing residential section of a certain city. Along the route of this 12-in. line was a moderate-sized factory whose fire flow requirements were adequately met at that time. It is a recognized fact that fire flow consists only of that amount of water left after domestic consumption has been provided for. Ten years ago there was no difficulty in meeting both demands. Today, residential building in this particular area has occurred at such a rate that domestic consumption has increased several fold—to such an extent, in fact, that the amount remaining for fire flow is insufficient. Such situations occur from year to year in the regular test work of the Ohio Inspection Bureau. Sometimes the deficiency is so great that fire insurance rates have to be increased for certain individual buildings, unless the city is able to augment the supply within a reasonable period. Whether or not they are aware of it, most water works engineers are faced with this problem to some extent. In the event that the water works engineer is not sure how much fire flow may have been lost in his system because of increased consumption, the local insurance inspection bureau should be called on to assist in making the necessary tests.

Conclusions

Sometimes water systems are built or extensions made without first submitting the plans to an insurance inspection bureau. There is no harm in this—*if* the design produces the necessary results. The author is aware of a number of examples in recent years, however, in which this did not occur, and in which it was necessary to limit credit accordingly. In some instances,

the credit for the water system was no greater than that given a tank of water on a fire truck.

By this time the reader will have concluded that the Ohio Inspection Bureau is opposed to the use of 4-in. pipe to supply hydrants. Consultation with the local insurance inspection bureau or agent is recommended while a proposed system or extension is still in the design stage. Although, under some conditions, the use of 4-in. pipe may be approved, 6-in. pipe is generally considered the minimum requirement for small towns and 8-in. pipe for larger municipalities. The reader should bear in mind that an undersized pipe situation may exist even when pipes larger than 8 in. are involved. The fire flow requirements of a given town may not have changed appreciably since the system was designed, but the ability of the system itself to handle this fire flow may have diminished considerably. Pipe dreams need not be nightmares: when planning future systems or extensions, it is wise to consider possible future fire protection problems while still in the design stage.

Water Utility Safety in Seattle

The 1955 report on safety presented by J. Ray Heath, superintendent of water, Seattle, is illuminating. The water department became interested in a safety program "at the time of the Kansas City AWWA Convention" in May 1952. The start was slow. Most effort in the beginning was concentrated on the reduction of motor transportation accidents. That endeavor is starting to produce returns in fewer accidents as shown by the following statistics:

	1954	1955
Total number of vehicles	131	144
Total miles driven	1,024,543	1,094,671
Average miles driven per vehicle	7,821	7,602
Total number of accidents	27	19
Number of miles per accident	37,946	57,614
Frequency rate	2.635	1.735
Total cost of all accidents	$576.38	$359.62
Average cost per accident	$21.38	$18.93

The department is now ready to concentrate on an overall safety program with the naming of a full-time safety supervisor. This is a timely appointment, as the injury frequency rate for the department in 1955 was relatively high (33.45).

Monitoring Network for Measuring Radioactive Fallout

Merril Eisenbud

A paper presented on Dec. 16, 1955, under the sponsorship of AWWA, at the Engineers Joint Council's Nuclear Eng. and Science Congress, Cleveland, Ohio, by Merril Eisenbud, Mgr., New York Operation Office, Atomic Energy Com., New York, N.Y.

THE Health and Safety Laboratory of the US Atomic Energy Commission has been measuring radioactive fallout in the United States since 1951, when the weapons-testing program at Eniwetok atoll was augmented by the establishment of a continental test site in Nevada.

With the assistance and cooperation of the US Weather Bureau, the Commission set up a network of monitoring stations which, when tests are underway in Nevada, includes 89 stations. At other times, the number of stations is reduced to 41, a sufficient number of sampling sites for the more uniformly diffused radioactive debris that may originate from detonations beyond the continental limits.

Basic Mechanics of Fallout

The intense heat that accompanies the detonation of a nuclear device volatilizes the radioactive fission products as well as the various components of the test assembly. This mass of luminescent gas which forms the "fireball" sucks up varying amounts of dust from the ground by convection. The dust is initially radioactive. A portion of the convected material may reach the fireball and vaporize. Inert dust sucked into the fireball in the advanced stages of cooling may act as nuclei on which the fireball vapors condense as a radioactive coating. Some of the vapors will condense around ionic nuclei and form discrete fume particles which may or may not aggregate with the larger particles of inactive dust.

The enormous amount of radioactivity (1 min after detonation, a weapon equivalent to 20 kilotons of TNT creates 8.2×10^{11} curies gamma activity) decays rapidly, and at any subsequent time the activity can be approximated by the relationship

$$A = A_1 t^{-1.2}$$

where A_1 is the activity at one unit of time after the detonation and t is time. As a rule of thumb, the radioactivity will decrease tenfold for every sevenfold increase in time since the detonation.

The dispersion of radioactive particulates within the cloud is initially characterized by a wide range of particle size. Particles from less than 1 μ to about 10 μ in diameter are likely to be discrete spheres, whereas the larger particles are more apt to consist of fission products condensed on dust convected from the ground. Included in this portion of the dust are particles of relatively large diameter, often greater than 100 μ.

The radioactive particles form at great heights above the ground. As

they begin their descent to earth, they are carried cross country on a path determined by the wind patterns. The manner in which a particle descends through various layers of the atmosphere, each characterized by its individual turbulent properties, is not well understood.

A 100μ particle, assuming a density of three, settles by gravity at a terminal velocity of 180 fpm, and therefore sedimentation may play a dominant role in the descent of the relatively large particles. However, a 1μ particle of the same density will settle at approximately 0.02 fpm—a rate of fall that is not sufficient to explain the rapidity with which such particles sometimes reach the ground. The turbulent behavior of the atmosphere is a more important factor in the descent of relatively small particles than is gravitational settling. As with other atmospheric dust, the descent of particles of all sizes is greatly hastened in the region of precipitation where transport to the earth's surface may be accelerated by several effects.

From the time the fireball first begins to condense until the radioactive dust actually descends to the earth, a number of processes may influence the radiochemical properties of the dust. The fission products which are initially formed are undergoing decay, of course, and the actual radiochemical composition of a sample of fallout will always depend on the age of the material.

Table 1 lists the principal isotopes that are present at various periods after fission. When the fission products are well mixed, a sample will decay in proportion to the -1.2 power of time, as noted previously. Samples of fallout do not always decay acording to this scheme, however, although -1.2 is a good average figure and is valid for well mixed fission products. In actual practice it is observed that the slope of the exponential decay may vary between 0.8 and 1.8. In fact, from any given detonation, samples of fallout collected at different places are apt to decay at different rates. This is caused by the way in which the various fission products tend to "fractionate" during the period when the fireball is formed and cooled. An important example of this occurs with the two isotopes strontium-89 and strontium-90. Both

TABLE 1

Principal Isotopes Present at Various Periods After Fission

Isotope	Contribution to Fission Product Activity—*per cent*		
	After 1 week	After 1 month	After 1 year
Sr^{89}	2.1	6.4	2.6
Sr^{90}			1.9
Y^{90}			1.9
$_2Y^{91}$	2.4	7.2	4.0
Zr^{95}	2.4	7.6	7.0
$_2Cb^{95}$		3.7	15.3
Mo^{99}	10.0		
Ru^{103}	1.9	5.4	
Ru^{106}			2.4
$_1Rh^{103}$	1.9	5.3	
Rh^{106}			2.4
I^{131}	6.2	4.0	
I^{133}	7.2		
Te^{132}	7.0		
Xe^{133}	12.1	3.1	
Cs^{137}			1.5
Ba^{137}			1.5
Ba^{140}	8.8	11.1	
La^{140}	9.3	12.8	
Ce^{141}	4.8	11.1	
Ce^{144}		1.8	26.0
Pr^{143}	8.0	11.4	
Pr^{144}		1.9	26.1
Nd^{147}	4.1	4.3	
Pm^{147}			5.7
Pm^{149}	1.7		
Total	89.9	97.1	98.3

of these isotopes are derived from radioactive precursors krypton-89 and krypton-90, having half lives of 180 sec and 25 sec, respectively. Some of the radiostrontium is thus formed relatively late in the life of the fireball and after a considerable amount of condensation has already taken place. The large particles which fall out close to a detonation are actually found to be depleted of radiostrontium, with a corresponding enrichment in debris which falls out at greater distances.

Of particular interest to water works engineers is the fractionation which may take place by water solution. There is evidence that the various isotopes do not dissolve uniformly, but there have been relatively few radiochemical studies in this field. More information is needed on the way the various radioisotopes, initially present in fallout, partition themselves between the suspended solids and water of a reservoir, stream, or even a test tube sample.

Observations of fallout are based on the collection of airborne and settled dust samples which can be collected with relatively simple equipment and by uniform procedures.

Monitoring Stations

The fixed monitoring stations sample dust by collections on a 1-ft gummed surface supported on an acetate film mounted horizontally on a frame about 3 ft above the ground. The coating retains its adhesive properties when it is wet, and dust particles that are entrapped in raindrops are collected efficiently. Sampling is continuous and the gummed films are changed each day and mailed to the Atomic Energy Commission's Health and Safety Laboratory in New York, where their radioactivity is assayed. The 89 cities at which stations are located are listed in Table 2.

As preparation for analysis, the samples are ashed at 550°–600°C. This results in the loss of some volatile isotopes, such as those of iodine and ruthenium, but these comprise less than 10 per cent of the total activity. This defect in procedure is justified by the simplicity of the operation.

The small amount of residual ash is transferred to plastic planchets that are sealed between two layers of vinyl tape and loaded in reels of 100 samples on automatic beta counters. These counters have a background of 7–10 counts per minute and efficiencies of the order of 10 per cent. Samples are counted for 20 min or until 640 counts are reached if this should occur before 20 min have elapsed. Blanks and standards are sealed into every tape. The counts are extrapolated to the midpoint of the sampling day and the collection is reported as distintegrations per minute per square foot, figured as an average of the 24-hr count.

This method of monitoring fallout is exceedingly sensitive. It has been observed in field studies that a general rise in the gamma background of 10^{-4} roentgen per hour (r/hr) is associated with fallout of approximately 10^{6} disintegrations per minute per square foot. The counting procedure permits detection of a daily fallout of as little as 10 disintegrations per minute per square foot. It is thus possible to detect radioactivity that produces a general elevation of background of about 10^{-9} r/hr. The normal gamma background count—which is caused by cosmic rays, radiopotassium, radium, and other natural sources of radioactivity—varies somewhat in the range of 5×10^{-6} to 5×10^{-5} r/hr. The methods utilized in the monitoring network

thus make possible estimations of minute amounts of radioactivity that are incapable of measurably affecting the general gamma radiation background of an area.

It is obvious that no single sampling procedure provides the ideal method for estimating the deposition of radioactive dust under all conditions. The deposit on any given area will depend somewhat on the character of the surface presented. When there is no rainfall, for example, dry fallout may drift slightly with other windblown dusts. In this situation, the gummed-film technique may yield a high estimate of the average fallout because it will tend to collect dust that is being redistributed laterally.

A study was undertaken to compare the effectiveness of the gummed paper compared with a high walled pot. The pot was a simple stainless-steel vessel 12 in. in diameter and 18 in. high. It was placed beside the gummed paper standard in New York, and the contents were removed for radioassay once a week. Data on radioactivity collected by the two methods over a period of many months were compared and there was quite close agreement. During a 49-week period for which

TABLE 2

Collection Stations

Location	Location	Location
Mobile, Ala.	Louisville, Ky.*	Syracuse, N.Y.
Montgomery, Ala.	New Orleans, La.*	Cape Hatteras, N.C.*
Flagstaff, Ariz.	Caribou, Me.	Fargo, N.D.
Phoenix, Ariz.	Baltimore, Md.	Williston, N.D.
Tucson, Ariz.*	Boston, Mass.*	Cleveland, Ohio*
Yuma, Ariz.	Alpena, Mich.	Medford, Ore.*
Fort Smith, Ark.	Detroit, Mich.*	Portland, Ore.
Eureka, Calif.	Marquette, Mich.	Philadelphia, Pa.*
Fresno, Calif.	Grand Rapids, Mich.	Pittsburgh, Pa.*
Los Angeles, Calif.*	Minneapolis, Minn.*	Providence, R.I.
Sacramento, Calif.	Jackson, Miss.	Charleston, S.C.
San Diego, Calif.	Kansas City, Mo.*	Huron, S.D.
San Francisco, Calif.*	St. Louis, Mo.*	Rapid City, S.D.*
Colorado Springs, Colo.	Billings, Mont.*	Knoxville, Tenn.*
Denver, Colo.	Helena, Mont.	Memphis, Tenn.*
Grand Junction, Colo.*	Kalispell, Mont.	Abilene, Tex.
Pueblo, Colo.	Scottsbluff, Neb.*	Amarillo, Tex.
New Haven, Conn.*	Elko, Nev.	Corpus Christi, Tex.*
Washington, D.C.	Ely, Nev.	Dallas, Tex.*
(Silver Hill, Md.)*	Las Vegas, Nev.*	Del Rio, Tex.
Jacksonville, Fla.*	Reno, Nev.	Port Arthur, Tex.
Miami, Fla.*	Winnimucca, Nev.	Milford, Utah
Atlanta, Ga.*	Concord, N.H.*	Salt Lake City, Utah*
Boise, Idaho*	Albuquerque, N.M.*	Lynchburg, Va.
Pocatello, Idaho	Roswell, N.M.	Seattle, Wash.*
Chicago, Ill.*	Albany, N.Y.	Spokane, Wash.
Des Moines, Iowa*	Binghamton, N.Y.*	Green Bay, Wis.
Concordia, Kan.	Buffalo, N.Y.*	Milwaukee, Wis.
Goodland, Kan.	New York (LaGuardia), N.Y.*	Casper, Wyo.
Wichita, Kan.*	Rochester, N.Y.*	Cheyenne, Wyo.

* Stations in operation even when continental tests are not in progress.

analyses of all data had been correlated, the regression of the radioactivity collected weekly by the stainless steel vessel, in relation to the weekly collection by gummed-paper, was 1.17 ± 0.19. This is not significantly different from 1.

Collection methods, utilizing pots or pans for collection of total rainfall, are disadvantageous in practice because of the need to transfer and handle the wet samples before shipping them to a central radiochemical facility.

period covered by the present report, almost 300,000 samples were collected and assayed for radioactivity. Cumulative data, extrapolated to Jan. 1, 1956, are given in Fig. 1, which presents estimates of the fallout for each state, except Nevada, based on data from the 89 stations listed in Table 2. Nevada is not included because local fallout in the vicinity of the proving grounds is quite variable and makes it difficult to assign a single representative value. It is seen that the total

Fig. 1. Cumulative Fallout in the United States, 1951–1956

Data shown are comprised from actual data for the period 1951 to August 1955 which has been extrapolated to Jan. 1, 1956. The extreme differences in total fallout are primarily caused by wind patterns.

Results

The cumulative findings have been reported in two previous reports by the Commission (*1, 2*). The present paper brings the data up to date by including the fallout observed during Operation TEAPOT, a series of tests conducted in Nevada during the spring of 1954.

From the time the monitoring program was started until July 1955, the fallout varies from 22 millicuries (μc) per square mile in California to 260 in Colorado. These extremes are primarily caused by the wind patterns that normally prevail in relation to the location of the continental test site near Las Vegas. Although the data of Fig. 1 include fallout from both the Marshall Islands and the Nevada tests, most of the fallout in the United States is from Nevada. This accounts for the low

value in California, which is to the west of the Nevada test site and therefore not often in the path of the fallout.

The cumulative data are characterized by marked uniformity. Although the highest values reported are more than ten times greater than the lowest values, the spread of values within large areas of the country is relatively narrow.

Discussion

A comparison of collected data with naturally occurring radioactivity offers a useful means of gaining an appreciation of the significance of the data, particularly with regard to their biological significance. Natural radioactivity originates from cosmic sources and from the naturally occurring radioisotopes, of which its daughter products and crypton-40 are the most important.

The average concentration of radium-226 in soil is of the order of 10^{-13} to 10^{-12} curies per gram. Taking the lower concentration as a conservative basis for comparison and limiting consideration to the top 12 in. of the soil, radium-226 is calculated to be present in excess of 1,000 curies per square mile, considerably greater than the total fallout reported to date.

The isotope, strontium-90, which is present in fallout, is regarded as the constituent of principal biological significance. This is because of its relatively long half life of 25 years and the fact that its chemical similarity to calcium makes it possible that strontium can enter into biological systems along with calcium and ultimately be deposited in human bone. As is well known, this is also true of radium.

Analyses of soil samples from various parts of the country disclose the strontium-90 content of the total fallout radioactivity to be 1 to 5 per cent at the present time. A representative figure for the amount of strontium-90 now present is 1 μc per square mile, or one-thousandth the amount of radium normally present in the upper 12 in. of soil.

Although the present quantities of radioactivity are minute in relation to the radioactivity normally present in the earth's crust, the fallout is readily measurable with the radiochemical equipment available to many laboratories. The opportunity exists for valuable tracer scale experiments to study the fate of fission products in soils, reservoirs, or streams. This opportunity is recognized in many universities where the trace quantities of fallout are utilized to develop decontamination procedures. At other laboratories, both in the universities and at Atomic Energy Commission installations, the fate of fallout is being studied in relation to the complex physical and biological interrelationships on land and in lakes, oceans, and streams.

For the nuclear age which is approaching, whether it brings war or peace, the information obtained in these studies will guide the engineer and scientist protecting man from this newest addition to the long list of physical and chemical waste products of technological advance that have troubled man since he first wallowed in the kitchen middens of prehistoric time.

References

1. Eisenbud, M. & Harley, John H. Radioactive Dust From Nuclear Detonations. *Science*, **117**:141 (1953).
2. Eisenbud, M. & Harley, John H. Radioactive Fallout in the United States. *Science*, **121**:677 (1955).

Radioactive Fallout in Water Supply at Portland, Me.

Rolf Eliassen and Robert A. Lauderdale

A paper presented on Jun. 14, 1955, at the Annual Conference, Chicago, Ill., by Rolf Eliassen, Prof. of San. Eng., and Robert A. Lauderdale, Research Assoc., both of Massachusetts Institute of Technology, Cambridge, Mass.

DETONATION of the atomic and hydrogen bombs has led to temporary increases in the level of radioactivity in the atmosphere. Rainstorms occurring in the path of this nuclear debris may cause radioactive fallout, or, more properly, rainout, and a consequent increase in radioactivity of public water supplies. In view of this, the general manager of the Portland Water District requested the authors to determine the increase in radioactivity of the Portland water supply following the Nevada atomic weapons tests during the winter and spring of 1955.

Lake Sebago, one of the famous recreational areas of Maine, is the source of water for the Portland Water District. The area of the lake is 45 sq miles, and it has a drainage area of 450 sq miles. For 2 months of the period of analysis the lake was covered with snow and observations were therefore made under conditions of snow cover and open water.

Objectives

Samples of snow water and Lake Sebago water were analyzed for radioactivity from Feb. 11, 1955, through Jun. 24, 1955. The objectives of the studies were the following:

1. To determine the background radioactivity in Lake Sebago
2. To determine the increase of radioactivity in Lake Sebago following the detonation of nuclear weapons in Nevada
3. To determine the radioactivity of samples of snow overlying the ice on Lake Sebago during the winter months
4. To measure the rate of decay of radioactive contaminants in snow
5. To determine the effect of the sudden release of radioactivity from melting snow as the ice went out of Lake Sebago
6. To determine the radioactivity of tap water samples of Lake Sebago water taken from the Portland distribution system
7. To compare the observed levels of radioactivity with standards of safety as promulgated by the National Bureau of Standards
8. To perform radiochemical analyses on the snow and water samples for strontium
9. To compare strontium findings with maximum allowable concentrations.

Analytical Procedures

Samples of snow, lake water, and tap water were collected by personnel

of the Portland Water District. One-liter samples of the water or melted snow were placed in polyethylene bottles. These were sent by mail to the laboratory. Upon arrival the samples were transferred to 1-liter beakers and evaporated, following acidification with hydrochloric acid. Samples which boiled during evaporation were covered with watchglass covers to prevent loss of sample from mist or spattering.

After the initial volume had been reduced to approximately 25 ml, each sample was transferred to small porcelain evaporating dishes for further reduction. During the transfer, two acid rinses and a final water rinse were used to insure complete cleaning of the beaker. Samples and rinse water were next taken completely to dryness, without boiling, in the evaporating dishes. The final transfer of the sample was made from the evaporating dish to the nickel-plated counting dish. The sample was then placed under infrared lamps and again taken to dryness. During this transfer, one drop of concentrated acid was used in three or four drops of water to dissolve any residue on the sides of the evaporating dish. This was followed by two or three rinses with water to achieve complete transfer of the sample residue.

The dried samples were counted, usually on the same day as received, on end window–type Geiger counters. The particular counter used consisted of an automatic sample changer and timer, and a scaler with preset count. A Geiger tube with a mica window thickness of approximately 1.8 mg per square centimeter was used.* The counting efficiency, as determined with a Radium D+E Standard, was approximately 20 per cent. Each sample was counted four times for a preset count of 400, thus giving a total of 1,600 counts per sample. A background count was made either immediately preceding or immediately following each sample count. The final count given was calculated by subtracting the average of the four background counts from the average of the four sample counts.

* The sample changer, timer, and Geiger tube used were products of Tracerlab, Inc., Boston, Mass., and the scaler was a product of the Atomic Instrument Co., Cambridge, Mass.

TABLE I

Radioactivity Assays of Snow and Lake Water Samples From Lake Sebago

Collection Date	Source	Activity—*cpm/l**
	Period 1	
Feb. 11	snow	21
Feb. 11	tap	1.5
Feb. 16	snow	94
Feb. 16	tap	1.7
Feb. 17	snow	22
Feb. 17	tap	6.5
Feb. 21	snow	29
Feb. 21	tap	1.6
	Period 2	
Mar. 28	snow	1,621
Mar. 29	snow	765
Mar. 30	snow	640
Mar. 31	snow	404
Apr. 1	snow	149
Apr. 2	snow	132
Apr. 3	snow	136
Apr. 4	snow	79
Apr. 4	tap	6
Apr. 5	snow	34
Apr. 6	lake	41
Apr. 7	lake	6
Apr. 8	lake	6
Apr. 9	lake	10
Apr. 10	lake	15
Apr. 11	lake	11
Apr. 11	tap	3.5
Apr. 12	lake	12
Apr. 13	lake	6

* The abbreviation cpm stands for counts per minute.

Results

A portion of the results is given in Tables 1 and 2. These data show results of analyses made during three periods: Period 1, prior to the first test blast in Nevada; Period 2, when the ice covering Lake Sebago was melting; and Period 3, after the lake was completely free of ice.

TABLE 2

Radioactivity Assays of Lake and Tap Water Samples for Period 3

Collection Date	Activity—*cpm/l*	
	Lake Samples	Tap Samples
Jun. 13	8.7±1.6	6.7±1.6
Jun. 14*	10.1±1.7	5.6±1.5
Jun. 15	9.9±1.7	7.6±1.6
Jun. 16	7.4±1.6	9.8±1.7
Jun. 17*	12.2±1.8	7.5±1.6
Jun. 18	6.7±1.6	5.9±1.5
Jun. 20	9.0±1.7	11.2±1.8
Jun. 21*	9.1±1.7	4.7±1.5
Jun. 22	3.9±1.5	7.1±1.6
Jun. 23*	10.8±1.7	5.2±1.5
Jun. 24	10.0±1.7	10.0±1.7

* Tests in which there was an appreciable difference in activity between lake samples and tap samples.

Discussion

The data obtained prior to the first test blast clearly demonstrate that small quantities of radioactive materials may be present in rain and snow for considerable periods following a nuclear explosion. The radioactivity present in the samples taken before Feb. 24, 1955, probably arises from a mixtures of strontium-89 and -90, zirconium-95, yttrium-91, promethium-147, cesium-137, cerium-144, and ruthenium-106. Some of these elements decay into daughter products which are also radioactive.

Samples collected following the first test blast show increasing amounts of activity, all of which decayed much more rapidly than that present in previous samples. Decay data for five arbitrarily selected samples are shown graphically in Fig. 1. In this figure, counts obtained after the initial count have been plotted as percentage of the initial count. This was done for convenience only to facilitate comparison of the rates of decay of the different samples. The initial count (100 per cent) is plotted on the date of the first count made in the laboratory. In figures of this type, the important feature is the slope of the lines at any point, as this gives an indication of the age of the mixture. For a limited period following a single blast, the radioactive decay can be approximated by the equation

$$A = A_0 t^{-1.2}$$

in which A is the activity at time t, A_0 is the activity at unit time, and t is the elapsed time since fission occurred. The rate of decay changes rapidly with time and is most rapid immediately following the explosion. The equation holds only for the radioactivity resulting from a single test blast and not for mixtures of radioactivity from overlapping tests. For this reason, the decay of samples collected after the first test should more closely follow the equation than the decay of samples collected after several tests had occurred. In Fig. 1, those samples which decay at nearly the same rate contain fall-out with essentially the same age.

The period during which Lake Sebago was thawing is of interest in that the expected release of radioactivity caused no apparent increase in the radioactivity of the tap samples. To determine if this were caused by adsorption of radioisotopes on the mains of the distribution system, additional

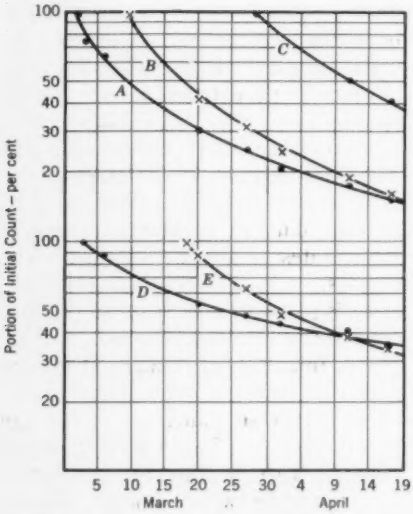


Fig. 1. Decay Curves for Selected Snow Samples

The data are for the following: Curve A—*Feb. 28; Curve* B—*Mar. 9; Curve* C—*Mar. 28; Curve* D—*Mar. 2; and Curve* E—*Mar. 16.*

daily samples were taken during the period from Jun. 13–24, 1955, as shown in Table 2. These data show that appreciable differences in radioactivity in the lake and tap samples occurred only on four occasions. These differences are not substantial, however, and because they occurred on only 4 out of 11 days, they could be caused by errors in sampling rather than by actual significant differences in counts. On the basis of these data, it appeared that the absence of a marked increase in the radioactivity in the water as the ice melted was because of the following:

1. Rapid decay between the time fallout occurred and the time the lake thawed, as indicated by the rapidly decreasing count between Mar. 28 and Apr. 5

2. The large dilution afforded by the uncontaminated water in the lake beneath the ice.

Strontium Concentrations

It is of interest in the analysis of water samples to determine if the activity present is sufficient to constitute a health hazard to consumers of the water. Values from maximum permissible concentrations (MPC) have been taken from the *National Bureau of Standards Handbooks,* No. 52 (*1*). For radioisotopes in water the values are as follows:

1. For unknown radioactive beta (β) or gamma (γ) emitters in water to be used for periods of a few months, 10^{-7} microcuries per milliliter (μc/ml)

2. For continuous exposure to strontium-89, 7×10^{-8} μc/ml

3. For continuous exposure to strontium-90 + yttrium-90, 8×10^{-7} μc/ml.

These values are for the activity in addition to any radioactivity which may be present naturally in the water. The value of 10^{-7} μc/ml for unknown β and γ emitters is to be used only until an analysis can be made to determine the identity of the unknown contaminant. Following analysis, the MPC can be calculated for the isotopes present.

In order to convert the data obtained by counting to microcuries, it is necessary to know the counting efficiency. It was estimated that this counting efficiency for the Portland samples was approximately 10 per cent for gross β counts and approximately 20 per cent for the strontium counts which will be given later. On this basis, a gross β count of 22 counts per minute (cpm) per liter at 10 per cent

efficiency is equivalent to 10^{-7} μc/ml. A strontium count of 44 cpm per liter at 20 per cent counting efficiency is also equivalent to 10^{-7} μc/ml. The MPC of strontium 90–yttrium 90 in water to be used continuously is thus 352 cpm per liter, and the MPC for strontium-89 is 30,800 cpm per liter. It should be emphasized that the values given are for continuous exposure and do not apply to either emergency exposure or to short-term exposure. Under emergency conditions, the permissible exposure for mixed fission products for a 10-day period following a blast is of the order of 50,000 times higher than the 10^{-7} μc/ml figure quoted above. The highest count for any sample received from the Portland Water District was 2,163 cpm per liter, obtained on a snow water sample collected on Mar. 9. Using the conversion factor given above, this is equivalent to 98.5×10^{-7} μc/ml, or approximately 10^{-5} μc/ml. While this figure is 100 times greater than the MPC for continuous exposure, it is also at least 500 times less than the MPC for a short-term exposure. A decay study of this sample showed that after 1 month the remaining radioactivity amounted to only 16 per cent of that originally present at the time of analysis.

Analyses of tap samples indicated that the activity of the water, including any natural radioactivity present, was consistently less than 10^{-7} μc/ml. The greatest amount of activity observed was 11.2 cpm per liter, or approximately 0.5×10^{-7} μc/ml.

Eight snow samples were analyzed radiochemically to determine the active strontium present, and the results are given in Table 3. The procedure used did not distinguish between strontium-89 and strontium-90, but gives only combined strontium. With a fresh mixture of fission products, the predominant strontium isotope is strontium-90 for the first 2 days following fission, and strontium-89 for the period from 2 days until a little more than 1 year after fission. The strontium-90 isotope comprises less than 1 per cent of the total gross beta activity until approximately 250 days after fission occurred. For the most part, therefore, the strontium isolated from the sample analyzed should be strontium-

TABLE 3

Radioactivity and Radiostrontium in Snow on Lake Sebago After Bomb Blasts, 1955

Collection Date	Gross Beta Radioactivity *cpm/l*	Strontium Radioactivity			
		cpm/l	*per cent of total count*	*μc/ml × 10⁹*	*per cent of MPC × 10²**
Feb. 25	101	4.1	4.1	0.9	1.3
Mar. 1	222	5.5	2.5	1.2	1.7
Mar. 8	690	8.7	1.2	2.0	2.9
Mar. 12	611	22.5	3.7	5.1	7.3
Mar. 15	464	5.7	1.2	1.3	1.9
Mar. 23	535	12.8	2.4	2.9	4.1
Mar. 25	439	8.1	1.8	1.8	2.6
Mar. 26	378	6.0	1.6	1.4	2.0

* Based on MPC value of 7×10^{-9} μc/ml for strontium 89 in water to be contaminated continuously.

89, with a very small percentage of strontium-90. The fraction of strontium found for the samples listed agrees quite well with values in the literature for fission products mixtures of less than 1 week old (*2*).

The percentages of maximum permissible concentration given in the last column of Table 3 were calculated using the permissible concentration in water which is to be continuously contaminated as a basis. As was pointed out previously, allowable concentrations for short-term exposure are considerably higher, and the calculations used therefore include an additional factor of safety. Multiplying the highest observed tap water count by the highest percentage of strontium shown in Table 3, it was calculated that the strontium was 11.2×10^{-2}, or 0.45 cpm per liter.

Assuming that this strontium count is due entirely to strontium-89, for which the long-term MPC is roughly 30,800 cpm per liter, it can be seen that the strontium in the Portland tap water could be increased by a factor of about 70,000 before exceeding the limits specified by the National Bureau of Standards in its handbook (*1*). Making the much more improbable assumption that the 0.43-cpm per liter value was entirely caused by strontium-90, the count after the strontium comes to equilibrium with yttrium would be about 0.9 cpm per liter. Even on this extreme basis, the strontium content of the water is some 400 times less than the MPC of approximately 352 cpm per liter permitted for water which is to be used continuously.

Acknowledgment

The authors wish to thank Herman Burgi Jr., general manager of the Portland Water District, for permission to publish the data given in this report, and Harold Scales, chemist, also of the Portland Water District, who cooperated fully in the collection of samples throughout the entire program.

References

1. Maximum Permissible Amounts of Radioisotopes in the Human Body and Maximum Permissible Concentrations in Air and Water. *National Bureau of Standards Handbooks*, No. 52 (Mar. 20, 1953).
2. Hunter, H. F. & Ballou, N. E. Fission Product Decay Rates. *Nucleonics*, **9**:C-7 (Nov. 1951).

Effect of High-Level Gamma Radiation on Disinfection of Water and Sewage

Gerald M. Ridenour and Edward H. Armbruster

A contribution to the Journal by Gerald M. Ridenour, Prof., and Edward H. Armbruster, Assoc. Prof., both of the Dept. of Environmental Health, School of Public Health, Univ. of Michigan, Ann Arbor, Mich.

THE principle of applying ionizing radiations to the control of bacteria was first suggested in 1896 (*1*). Ultraviolet radiations were probably the first radiations to be successfully applied to bacterial control on a large scale. This type of radiation, however, has a lower power of penetration and its application is therefore limited in range. In the past few years, radiations of greater penetrative power, such as cathode, gamma, and X rays, have begun to be available from sources large enough to permit their use for control of bacteria and viruses on a practical application level. Current research indicates that from 1,000,000 to 3,000,000 reps * of gamma radiation are required for sterilization of foodstuffs and pharmaceutical preparations (*2–5*). Other applications of bacteria control do not require complete sterilization, but merely a high percentage of reduction in numbers. Such an application is in the disinfection processes of water and sewage treatment.

The study described here has been made to determine whether presently available high-level sources of gamma radiation offer any promise in the field of water and sewage disinfection.

* "Roentgen equivalent, physical," a unit of dosage of ionizing radiation absorbed by organic tissue.

Procedure

The test samples included in this study consisted of normally contaminated sewage and surface waters, and laboratory-contaminated waters. The sewage samples used were primary–settling tank effluent and final plant effluent prior to chlorination. The sewage samples were collected at the Ann Arbor, Mich., sewage disposal plant which utilizes the activated-sludge treatment. The surface waters were collected from the Huron River at two separate sampling points. One sample was taken 0.2 mile upstream from the sewage plant outlet, and the other sample was collected approximately 2 miles downstream from the outlet. The laboratory-prepared test waters consisted of buffered saline base to which a small amount of a 24-hr nutrient broth culture of the selected test organism had been added to give approximately 2×10^7 organisms per milliliter.

Test water samples of approximately 150 ml were placed in bacteriological dilution bottles and securely stoppered. The samples were then irradiated at a rate of 3,000 roentgens per minute. The radiation source for this experiment was 10 kilocuries of cobalt-60. This isotope emits two gamma radiations of 1.10 and 1.30 million electron-

volts (Mev). The conditions of this experiment were such that only the gamma radiations were utilized. Total time of exposure to the radiation source was varied with the different aliquots of the test sample to obtain the desired series of dosages.

Colon indices, Streptococcus indices, and total counts were determined to measure the lethal effect of the radiation on the sewage and surface water samples. The organisms included for pure culture study of the lethal effects of gamma radiation in the laboratory prepared water were *Esch. coli, Aer. aerogenes, Streptococcus faecalis, Micrococcus aureus, Shigella sonnei, Shigella paradysenteriae* Flexner, *Salmonella typhosa, Salmonella paratyphosa B, Salmonella* sp., and *Bacillus subtilis.*

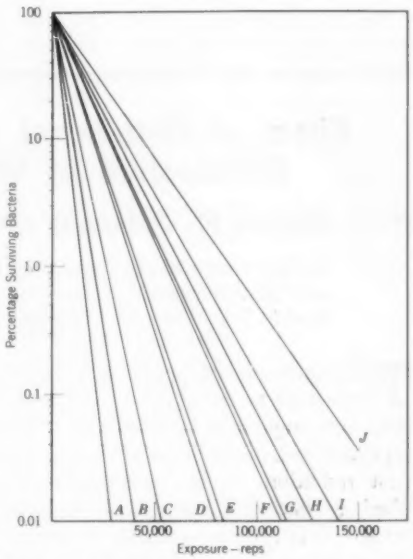


Fig. 1. Lethal Effect of Gamma Radiation

Lines indicate data for the following: A—Aer. aerogenes; B—Esch. coli; C—Shigella paradysenteriae *Flexner*; D—Salmonella typhosa; E—Shigella sonnei; F—Salmonella sp.; G—Micrococcus aureus; H—Salmonella paratyphosa B.; I—Streptococcus faecalis; *and* J—Bacillus subtilis. *The test samples consisted of organisms in laboratory-prepared waters.*

Results

Figure 1 shows the results of gamma radiation on pure cultures of some various organisms typical of the bacterial flora which can be found in sewage or polluted waters. A dosage of 50,000 reps was sufficient to produce greater than 99-per cent reduction of five of the ten test organisms. When the dosage was raised to 100,000 reps, all organisms, including the spore forming *Bacillus subtilis,* were reduced by 99 per cent or more. Of the organisms studied, the coliform types *Esch. coli* and *Aer. aerogenes* were the most susceptible to the gamma radiation. The most resistant were *Streptococcus faecalis* and *Bacillus subtilis.*

The lethal effect of gamma radiation on the polluted river water is shown by reductions in total bacteria count, coliform index, and streptococcus index in Table 1. Taking into account the method of obtaining an index per 100 ml of water and the relatively low numbers of streptococci in these water samples, the data obtained provide an excellent correlation with the results obtained from the studies of pure cultures. It is interesting to note that a dosage of only 25,000 reps was sufficient to demonstrate a very high reduction in the total numbers of the mixed bacteria flora in the river samples. The coliform count of the upstream sample was reduced from 540 per 100 ml to 6.8 and less than 1.8 at dosages of 25,000 and 50,000 reps, respectively, while the downstream

coliform indices dropped from 35,000 to 44 and 2 with the same dosages. The streptococcus index was too low to give an accurate picture, but, nevertheless, a good reduction in numbers was demonstrated for both samples with the 50,000-reps exposure.

The results of irradiation of highly polluted waters, such as sewage, with respect to the effect on total count, coliform index, and streptococcus index are shown in Table 2. The percentage of surviving organisms after gamma radiation exposures ranging from 50,000 reps to 250,000 reps are plotted in Fig. 2.

The results indicate that the organisms present in the primary-tank effluent were apparently more resistant to radiation than those present in the plant effluent. Even so, however, the coliform index was reduced 99 per cent by 50,000 reps, and the total count reduced the same amount by 100,000 reps in both samples. The mixed streptococci from the primary effluent appeared more resistant than any of the other organisms examined in this study, requiring a dosage of 250,000 reps to produce a 92-per cent reduction in numbers. The streptococci of the plant effluent was much more susceptible to radiation because a dosage of 100,000 reps was found to be sufficient to reduce their numbers approximately 99 per cent.

Figure 3 presents the results obtained on total-bacteria count when the sewage plant effluent was irradiated at pH 5, 7, and 8.5. At 50,000 reps, the reduction in count was 99.45, 99.48, and 99.55 per cent at pH of 5, 7, and 8.5, respectively. At dosages of 100,000 reps and 150,000 reps the lines tended to diverge slightly, but the numbers of survivors were too low to be statistically significant.

TABLE 1

Lethal Effect of Gamma Radiation on Bacteria in Polluted River Water

Radiation Exposure *reps*	Above Sewage Plant			Below Sewage Plant		
	Total Count per ml	Coliform Index per 100 ml	Streptococcus Index per 100 ml	Total Count per ml	Coliform Index per 100 ml	Streptococcus Index per 100 ml
0	4,000	540	79	7,700	35,000	540
25,000	90	6.8	130	95	49	70
50,000	44	<1.8	11	50	2	33
100,000	10	<1.8	13	17	<1.8	23
150,000	3	<1.8	11	11	<1.8	<1.8

Discussion

As might be expected, the various organisms exhibited quite a difference in their radiosensitivity. *Aerobactor aerogenes* was the most sensitive organism tested. This was closely followed by *Esch. coli*. The others listed, in order of increasing resistance, were *Shigella paradysenteriae* Flexner, *Salmonella typhosa, Shigella sonnei, Salmonella* sp., *Micrococcus aureus, Salmonella paratyphosa B, Streptococcus faecalis,* and the spore-forming *Bacillus subtilis,* the most resistant organism of the series. Better than 99 per cent reduction in numbers of the *Bacillus sub-*

tilis was obtained in the pure culture studies by 100,000 reps of cobalt-60 radiation, while only 25,000 reps demonstrated equal effectiveness against the coliform organisms. It is interesting to note that a dosage of 50,000 reps was sufficient to produce at least a 95-per cent reduction in numbers in all the nonsporulating organisms. Sterility was not achieved for all organisms when the initial numbers were in the magnitude of 2×10^7 per ml, even at 1,000,000 reps.

The effectiveness of only 25,000 reps in reducing the total count of the river waters from several thousand to less than 100 per ml indicates that the bacterial flora from this source was quite susceptible to radiation. The reduction in numbers of the naturally occuring coliform and streptococci indicates that they closely approximate the results obtained from the stock culture studies.

At first inspection, it appears as though the organisms present in the primary-tank effluents are more resistant to radiation than the organisms in the final effluent. This is perhaps not true, however, because of two factors. The first is the protective action of organic matter in the water against free radicals produced by the radiation. These free radicals will be consumed by the organic material as well

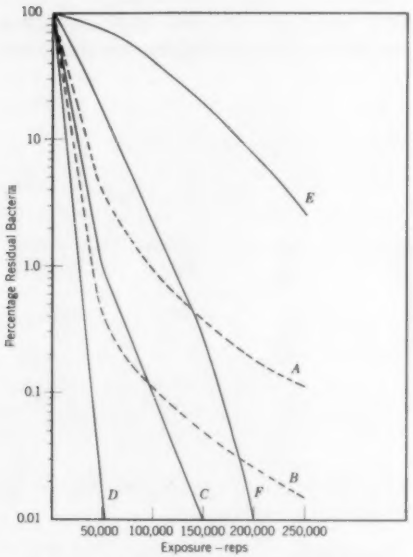


Fig. 2. Bactericidal Effect of Gamma Radiation on Sewage

Lines indicate data for the following: A—*total count, primary-tank effluent;* B—*total count, plant effluent;* C—*coliform count, primary-tank effluent;* D—*coliform count, plant effluent;* E—*streptococci count, primary-tank effluent; and* F—*streptococci count, plant effluent.*

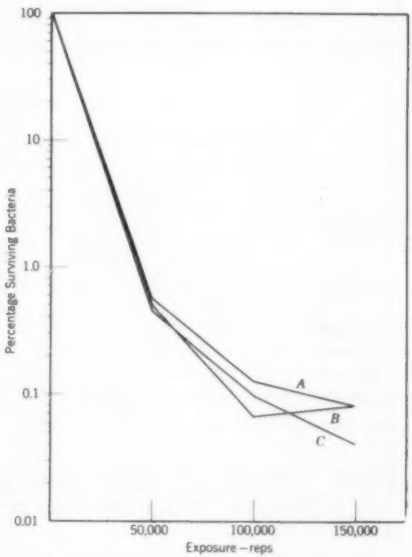


Fig. 3. Lethal Effect of Gamma Radiation on Sewage Effluent at pH 5, 7, and 8.5

The pH values are as follows: A—*8.5;* B—*7; and* C—*5*

as the bacteria in the same fashion that chlorine is consumed. Because the primary effluent contains much more material capable of reacting with these free radicals than does the oxidized effluent, the protective action would be more pronounced in the former. The second factor is the effect of the clumping of the bacteria with or without organic matter. Lea (*6*) and Gates (*7*) have reported that this condition will be the cause of death curves which experimentally do not follow the expected exponential shape. This is explained by the fact that when a large proportion, or even all but one organism in a clump, are killed, the entire clump still gives rise to a colony. Therefore, no lethal action would be measured until the dosage is sufficient to produce a 100-per cent kill of the clump.

Apparently, pH is not a significant factor affecting the lethal action of gamma radiation against bacteria. The results at pH 5, 7, and 8.5 were within experimental error of being identical.

Summary

Investigations were made with respect to the effect of high-level cobalt-60 gamma radiation in reducing bacteria populations in contaminated water and sewage.

Studies were made with the use of ten stock-culture, typical, waterborne organisms and also the natural-borne bacterial flora of water and sewage.

In the pure-culture studies of the ten typical waterborne organisms, a dosage of 100,000 reps was sufficient to kill 99 per cent or more of the organisms. The coliform organisms proved to be the most susceptible to radiation. *Strep. faecalis* and *B. subtilis* were found to be the most resistant.

A dosage of 25,000 reps was sufficient to demonstrate very high reductions in the total populations present in naturally polluted river waters.

Higher dosages were indicated for sewage, probably because of the protective action of organic matter and the clumping of the organisms. A dosage of 100,000 reps was sufficient to reduce the numbers of organisms by 99 per cent in the primary effluent. The plant effluent required only one-half that amount for similar reductions.

The pH of the water over a range of 5–8.5 was found to have no influence on the bactericidal action of the gamma radiation.

TABLE 2

Effect of Gamma Radiation on Total Count, Coliform, and Streptococci in Sewage

Radiation Exposure *reps*	Primary Effluent			Plant Effluent		
	Total Bacteria per ml	Coliform Index per 100 ml	Streptococcus Index per 100 ml	Total Bacteria per ml	Coliform Index per 100 ml	Streptococcus Index per 100 ml
0	8,000,000	35,000,000	1,400,000	85,000	54,000	92,000
50,000	300,000	350,000	1,100,000	320	79	5,400
100,000	97,000	35,000	160,000	74	<1.8	1,600
150,000	23,000	2,400	220,000	42	<1.8	540
200,000	14,000	350	170,000	44	<1.8	17
250,000	8,500	240	35,000	13	<1.8	2

Acknowledgment

This project was sponsored by the National Sanitation Foundation and the Phoenix Memorial Project, both at the University of Michigan, Ann Arbor, Mich.

References

1. MINCK, F. On the Question of the Effect of Roentgen Rays on Bacteria and the Possibility of Their Eventual Application. *Wochschr.*, **5**:101 (1896).
2. Utilization of Gross Fission Products. Progress Repts. No. 2–7. Engr. Research Inst., Univ. of Michigan, Ann Arbor, Mich. (1952–54).
3. O'MEARA, J. P. Radiation Chemistry and Sterilization of Biological Materials by Ionizing Radiations. *Nucleonics*, **10**: (Feb. 1952).
4. CONTROULIS, J.; LAWRENCE, C. A.; & BROWNELL, L. E. The Effect of Gamma Radiation on Some Pharmaceutical Products. *J. Am. Pharm. Assoc. Sci. Ed.*, **43**:65 (Feb. 1954).
5. CLIFCORN, L. E. The Food Industry's Attitude Toward Radiation Sterilization. *Nucleonics*, **13**:39 (Jan. 1955).
6. LEA, D. E. *Actions of Radiations on Living Cells.* Cambridge Univ. Press, Cambridge, England (2nd ed., 1955).
7. GATES, F. L. Bactericidal Action of Ultraviolet Light. *J. Gen. Physiol.*, **13**:249 (Nov. 1929).

Reprints Available

Reprints of the following articles, published in the JOURNAL during the preceding year, will be available from the Association in small quantities, at the prices noted, until the present stock is exhausted. Order by reprint number and author's name from: Order Dept., American Water Works Assn., Inc., 521 Fifth Avenue, New York 17, N.Y. **Prepayment required on orders under $2.** (Note: This list does not include specifications and similar documents kept permanently in stock.)

Reprint No.	Author	Title	Issue of JOURNAL	No. of Pages	Price per Copy
387	AWWA REPORT	Utility Employment Conditions	May 55	11	35¢
388	SWANSON ET AL.	Wye Branch Design	Jun 55	52	80¢
389	LUCE	Sizing Water Mains	Jul 55	5	20¢
390	HOWSON, AULTMAN, GALLAHER	Treatment Plant Design	Aug 55	9	25¢
391	GIDLEY	Municipal Management	Jun 55	4	15¢
392	DAVIS	National Water Policy	Sep 55	6	20¢
393	PANEL DISCUSSION	Water Resources Legislation	Sep 55	13	25¢
394	PANEL DISCUSSION	Suburban Service	Oct 55	28	40¢
395	MCCORMACK	Injury Rate Survey	Nov 55	6	20¢
396	WEIR; COMMITTEE REPORT	Air-Conditioning Charges	Nov 55	14	25¢
397	HANSON, AYRES, ELLIS	Fire Protection Charges	Dec 55	14	25¢
398	TASK GROUP REPORT	Fluoridation Census, 1954 Supplement	Dec 55	7	20¢
399	JACKSON	Atomic Energy	Dec 55	9	25¢
601	BURNETT, LEWIS	Tests of Coatings	Feb 56	21	35¢
602	INGRAM, CRABILL, SILVEY	Infestations in Water Systems	Mar 56	24	35¢
603	PANEL DISCUSSION	Lawn-sprinkling Load	Apr 56	17	30¢
604	YACKEY, CRUSE	Plastic Pipe Experience	Apr 56	10	25¢
605	KIRKENDALL	Cathodic Protection	Apr 56	13	25¢

Survival of Coxsackie Virus in Water and Sewage

Norman A. Clarke, Robert E. Stevenson, and Paul W. Kabler

A contribution to the Journal by Norman A. Clarke, In Charge, Virus Studies; Robert E. Stevenson, Virologist; and Paul W. Kabler, Chief of Microbiology; all of the Robert A. Taft San. Eng. Center, Cincinnati, Ohio.

THE possibility that virus diseases may be waterborne has become of increasing interest. During the past 10 years, several newly recognized viruses have been demonstrated to exist in the feces of apparently normal, as well as diseased, persons. Numerous investigators have identified the agents of poliomyelitis, Coxsackie disease, and infectious hepatitis in feces. A virus-like agent described by Gordon (*1*) and thought to be responsible for epidemic gastroenteritis was isolated from bacteria-free filtrates of feces from diseased persons. The viruses of the adenoidal-pharyngeal-conjunctival (APC) group described by Rowe (*2*) and Huebner (*3*), and responsible for upper respiratory disease and conjunctivitis, are also excreted in the feces. In addition, a number of unidentified viruses have been isolated in tissue cultures inoculated with fecal samples taken during mass surveys (*4, 5*). Melnick (*4*) has called these unidentified viruses "orphan" viruses, because no clinically recognized disease has been attributed to them. The number of viral species found in human feces may be greater than the number of pathogenic bacterial species.

These findings, coupled with the knowledge that both poliomyelitis and Coxsackie virus can be isolated readily from urban sewage (*6*), serve to focus attention on the significance of polluted water as a possible vehicle for the transmission of enteric virus disesaes. There are two reports of the isolation of a polio-like virus from water, one from a creek in Ohio (*7*) and another from a well in Sweden (*8*). These waters were also shown to be heavily contaminated by sewage. Waterborne outbreaks of infectious hepatitis have been reported several times from well waters shown to be polluted with sewage (*9–11*). No outbreak of a virus disease in which laboratory evidence indicated a treated water supply to be the source of infection has been reported.

Bell (*12*) has recently described outbreaks of APC virus infection which appeared to be associated with modern swimming pools. The virus was not isolated directly from the pool water, but epidemiological investigation indicated the pools to be a common factor in many cases. Contact infection while at the pool could not be ruled out, but neither could the pool water itself.

Because of existing potential hazard, a general investigation on the role of water in transmission of enteric virus agents has been undertaken. A previ-

ous paper (*13*) dealt with the resistance of Coxsackie virus to chlorination, and work on the effectiveness of flocculation in removing the virus from water is in progress. The present report deals with the survival times of Coxsackie virus in various natural, sterile, and polluted waters.

Test Samples

Group *A* Type 2 Coxsackie virus, in the form of a 20 per cent tissue suspension, was used in all experiments. This material titered 1×10^6 LD_{50} per 0.02 ml.*

Waters from various sources were used as a suspending medium for the virus. Ohio River water was taken at Public Landing in Cincinnati. Some experiments were conducted with other river or stream waters from southwestern Ohio, including Lytle Creek, a small stream polluted with domestic sewage (*14*). Several sampling points on this stream were selected, each representing a different degree of pollution. Raw sewage samples, obtained from a point in the sewage system of Cincinnati, consisted solely of residential wastes.

Test Procedures

In all experiments, sufficient stock virus in the form of a 20 per cent tissue suspension was added to the water or sewage samples to give an initial titer of 1,000 LD_{50} per 0.02 ml. These infected samples were then stored in the dark in glass-stoppered bottles at either 8°C or 20°C. Portions were removed at various time intervals and virus survival was determined by subcutaneous inoculation of 0.02 ml of undiluted supernate into 2–3-day old suckling mice. For mouse inoculation, the water suspensions were centrifuged at 18,000 rpm for 30 min, the supernate removed, and antibiotics added to inhibit bacteria. Sewage samples were suspended overnight in 50-per cent ether to destroy most of the bacteria before centrifugation and addition of antibiotic to the supernate. All inoculated mice were observed for 10 days for typical signs of Coxsackie virus infection (paralysis or death). At the

TABLE 1

Survival Time of Coxsackie Virus in Urban Sewage and Distilled Water

Storage Time—*days*	Mouse Assay Results	
	Deaths/ Inoculations	Percentage Mortality
Sewage—8°C		
5	9/9	100
20	13/17	76
41	9/19	47
61	8/15	53
117	0/5	0
Sewage—20°C		
5	14/15	93
20	4/11	36
41	1/19	5
61	0/8	0
Distilled Water—8°C		
5	19/19	100
41	6/6	100
142	11/11	100
272	11/11	100
Experiment discontinued		
Distilled Water—20°C		
5	16/16	100
41	18/18	100
135	0/9	0

* 1 LD_{50} is the amount of virus lethal to 50 per cent of the inoculated mice. The material titering 1×10^6 LD_{50}, therefore, could be diluted 1,000,000 times and still have this effect.

TABLE 2

Survival Time of Coxsackie Virus in Ohio River Water

Storage Time—*days*	Mouse Assay Results	
	Deaths/ Inoculations	Percentage Mortality
Raw River Water—8°C		
12	5/8	62
16	2/8	25
24	0/6	0
Autoclaved River Water—8°C		
16	9/9	100
32	9/9	100
67	10/10	100
102	9/9	100
150	10/10	100
171	2/9	22
Experiment discontinued		
Raw River Water—20°C		
6	12/20	60
28	0/6	0
Autoclaved River Water—20°C		
12	8/8	100
32	7/7	100
46	6/6	100
67	8/8	100
102	4/10	40
150	0/3	0

completion of the experiment the percentage of mortality in each group was calculated.

Test Results

The results of the first series of experiments on raw sewage, distilled water, and raw and autoclaved Ohio River water are presented in Tables 1 and 2. These data indicate that the rate of inactivation of Coxsackie virus in these waters is characteristically affected by temperature, in that the most rapid inactivation of virus occurred at the higher temperatures. The relatively rapid inactivation of Coxsackie virus in raw Ohio River water in contrast to its long survival in other waters led to the determination of survival times in the three Ohio Valley waters listed in Table 3.

The data in Table 3 suggest that the length of time Coxsackie virus survives in these river waters is related to the degree of pollution of the river—that is, survival time of virus was longest in Mill Creek, which is grossly polluted by domestic and industrial wastes, and shortest in the Little Miami, a relatively clean river.

TABLE 3

Survival Time of Coxsackie Virus in Various River Waters at 20°C

Water	Relative Pollution	Storage Time—*days*	Mouse Assay Results	
			Deaths/ Inoculations	Percentage Mortality
Little Miami River	None to little	4	0/8	0
		16	0/9	0
Ohio River	Moderate	4	4/10	40
		16	0/12	0
Licking River	Considerable	4	6/6	100
		16	0/9	0
Mill Creek	Gross	4	14/14	100
		16	4/7	57
		31	8/17	47
		72	0/5	0

This possible correlation between virus survival time and degree of pollution of surface water was more thoroughly examined by determining survival time in water samples from

TABLE 4

Survival of Coxsackie Virus in Lytle Creek Waters at 20°C

Storage Time—*days*	Sample Point *WR*	Sample Point 8.7	Sample Point 7.6	Sample Point *E*	Sample Point 6.5	Sample Point 5.2	Sample Point 4.2	Sample Point 1.0
	Survival Data*							
2	8 (1/12)	6.7 (1/15)	100 (4/4)	100 (9/9)	68 (17/25)	100 (10/10)	33 (2/6)	67 (6/9)
5	0 (0/5)	0 (0/8)	100 (8/8)	100 (7/7)	37 (3/8)	60 (3/5)	17 (1/6)	6.7 (1/15)
7	0 (0/12)	0 (0/10)	50 (9/18)	56 (5/9)	37 (3/8)	12 (1/8)	0 (0/9)	0 (0/6)
10			29 (2/7)	71 (5/7)	12 (1/8)	0 (0/10)	0 (0/8)	0 (0/6)
15			0 (0/6)	10 (1/10)	0 (0/5)			
20				0 (0/8)	0 (0/9)			
Initial coliform MPN	11,000	2,400	11,000	430,000	23,000	23,000	23,000	1,500
Initial 5-day BOD	3.5	3.0	15.0†	7.0	5.0	3.0	9.0	2.0

* Upper value is the per cent mortality, lower value (in parentheses) is the deaths per inoculations.
† Sample contained oil.

Lytle Creek. These samples were taken at selected points which were representative of relatively clean water (points *WR*, 8.7, 7.6); at the point of sewage effluent into the creek (*E*); and zones of decreasing pollution (points 6.5, 5.2, 4.2, and 1.0). The results of these examinations are summarized in Table 4. The good correlation between survival time of Coxsackie virus in surface water and the degree of pollution of such water is shown by these data.

Table 5 summarizes the time required to reduce 1,000 LD_{50} of Coxsackie virus to approximately 1 LD_{50} (99.9-per cent reduction). These data were obtained by selecting the sample storage time most nearly corresponding to a 50-per cent mortality (1 LD_{50}) in the inoculated mice.

Discussion

The potential hazard of sewage-contaminated water in transmitting virus diseases has been discussed by numerous investigators, but only recently have any data appeared on the survival time of the infectious agents in surface waters.

The virus of human poliomyelitis has been reported to survive in feces for at least 188 days in river water stored

at 4°C (*15*). This relatively long survival may reflect either the greater stability of the virus or the fact that the virus was added in the form of a fecal suspension, which imparted a high degree of "pollution" to the stored sample. Gilcreas and Kelly (*16*) recently investigated the survival of Coxsackie and Theiler's virus in both water and sewage. Their results and those reported here are hardly comparable because of differences in initial virus concentrations and other technical details, but in general, there is agreement with respect to temperature effects on survival times. Their experiments were carried out in spring water and sewage, and survival times for Coxsackie virus at 8–10°C were over 200 days, and, at 20–30°C, over 140 days. These survival times are, in general, considerably longer than results reported in this article would indicate, perhaps because the initial virus titers used in that study were over 10,000,000, as compared with 1,000 used in the experiments described here.

Chang (*17*), working with Theiler's virus (GD VII strain) at 1:2,000 dilution and a titer of 500 LD_{50} in tap water, raw river water, and tap water containing 10 per cent domestic sewage, reported that survival of virus was prolonged by lowering the temperature. He also observed that, at 23°C and 30°C, survival times were shorter in river water and domestic sewage than in tap water. Virus stored at 10°C in 10 per cent sewage was still demonstrable after 440 days. These results are comparable with observations made in the present experiments. The considerably longer survival time of Theiler's virus in 10-per cent sewage at 10°C, in contrast to Coxsackie virus in sewage, may be a reflection of inherent difference in the stability of the two viruses.

The high degree of correlation between Coxsackie virus survival times in natural waters and the degree of pollution of such waters raises questions of fundamental importance. All of the data suggest a protective effect of organic material in prolonging virus survival. The data in Tables 1 and 2, however, show that additional factors other than a "protective-colloid" effect operate in virus inactivation or survival.

TABLE 5

Time Necessary to Reduce 1,000 LD_{50} of Coxsackie Virus to 1 LD_{50}

Sample and Temperature	Time—*days*
Sewage—8°C	Approx. 50
Sewage—20°C	Less than 20
Distilled water—8°C	More than 272
Distilled water—20°C	41–135
Ohio River—8°C	12–16
Autoclaved Ohio River—8°C	150–171
Ohio River—20°C	Approx. 6
Autoclaved Ohio River—20°C	Approx. 102
Little Miami—20°C	Less than 4
Ohio River—20°C	Approx. 4
Licking River—20°C	4–16
Mill Creek—20°C	Approx. 47
Lytle Creek samples—20°C:	
WR	Less than 2
8.7	Less than 2
7.6	7
E	10–15
6.5	2–5
5.2	5–7
4.2	Less than 2
1.0	2–5

A water that is relatively free from microorganisms and nutritive material —that is, distilled water—permits longest virus survival. Autoclaving of raw Ohio River water also had a marked effect in prolonging virus survival. Apparently then, virus inactivation is in some way correlated with the normal microbiological flora of

natural waters. Any treatment, such as autoclaving, distillation, or added pollution, which destroys, removes, or alters this flora, influences virus survival. Experiments are under way to elucidate the factor or factors which inactivate Coxsackie virus in natural water.

References

1. Gordon, I.; Ingraham, H. S.; & Korns, R. F. Transmission of Epidemic Gastroenteritis to Human Volunteers by Oral Administration of Fecal Filtrates. *J. Exptl. Med.*, **86**:409 (1947).
2. Rowe, W. P., et al. Isolation of a Cytopathogenic Agent from Human Adenoids Undergoing Spontaneous Degeneration in Tissue Culture. *Proc. Soc. Exptl. Biol. Med.*, **84**:570 (1953).
3. Huebner, R. J., et al. Adenoidal-Pharyngeal-Conjunctival Agents: A Newly Recognized Group of Common Viruses of the Respiratory System. *New Eng. J. Med.*, **251**:1077 (1954).
4. Melnick, J. L. Application of Tissue Culture Methods to Epidemiological Studies of Poliomyelitis. *Am. J. Public Health*, **44**:571 (1954).
5. Ramos-Alvarez, M. & Sabin, A. B. Characteristics of Poliomyelitis and Other Enteric Viruses Recovered in Tissue Cultures from Healthy American Children. *Proc. Soc. Exptl. Biol. Med.*, **87**:655 (1954).
6. Melnick, J. L. Poliomyelitis and Poliomyelitis-Like Viruses of Man and Animals. *Annual Rev. Microbiol.*, **5**:309 (1951).
7. Toomey, J. A.; Takas, W. S.; & Weaver, H. M. Isolation of Poliomyelitis Virus from Creek Water by Direct Transmission to the Cotton Rat. *Am. J. Diseases Children*, **70**:293 (1945).
8. Kling, C. In Search of Poliomyelitis Virus in Drinking Water. *Intern. Bul. Econ. M. Research & Public Health*, **A40**:161 (1939–40).
9. Neefe, J. R. & Stokes, J., Jr. An Epidemic of Infectious Hepatitis Apparently Due to a Waterborne Agent. *J. Am. Med. Assoc.*, **128**:1063 (1945).
10. Farquhar, J. D.; Stokes, J., Jr.; & Schrack, W. D. Epidemic of Viral Hepatitis Apparently Spread by Drinking Water and by Contact. *J. Am. Med. Assoc.*, **149**:991 (1952).
11. Tucker, C. B.; Owen, W. H.; & Farrell, R. P. An Outbreak of Infectious Hepatitis Apparently Transmitted Through Water. *Southern Med. J.*, **47**:732 (1954).
12. Bell, J. A., et al. Pharyngoconjunctival Fever: Epidemiological Studies of a Recently Recognized Disease Entity. *J. Am. Med. Assoc.*, **157**:1083 (1955).
13. Clarke, N. A. & Kabler, P. W. The Inactivation of Purified Coxsackie Virus in Water by Chlorine. *Am. J. Hyg.*, **59**:119 (1954).
14. Katz, M. & Gaufin, A. R. The Effects of Sewage Pollution on the Fish Population of a Midwestern Stream. *Trans. Am. Fisheries Soc.*, **82**:156 (1952).
15. Rhodes, A. J., et al. Prolonged Survival of Human Poliomyelitis Virus in Experimentally Infected River Water. *Can. J. Public Health*, **41**:146 (1950).
16. Gilcreas, F. W. & Kelly, S. M. Relation of Coliform-Organism Test to Enteric-Virus Pollution. *Jour. AWWA*, **47**:683 (1955).
17. Chang, S. L. Annual Report on Germicides to the Quartermaster General, US Army (1946–47).

Mechanism of Polyphosphate Threshold Action

Gerald Corsaro, H. S. Ritter, William Hrubik, and Howard L. Stephens

A contribution to the Journal by Gerald Corsaro, Prof. of Physical Chemistry, Akron University, Akron, Ohio; H. S. Ritter, Chemist, Columbia-Southern Chemical Corp., Barbertown, Ohio; William Hrubik, Director, Research and Development, Patch Rubber Co., Akron, Ohio; and Howard L. Stephens, Research Chemist, Akron University, Akron, Ohio.

THE use of polyphosphates for the prevention of calcium carbonate deposits is widely practiced. Numerous references could be cited which clearly demonstrate the efficiency of this class of phosphates in water treatment applications. The practical results appear to depend, in part at least, on the ability of these phosphates to inhibit the precipitation of calcium carbonate from saturated solutions of that substance (*1*). Other references (*2*) report that the action of these phosphates is caused by the adsorption of the phosphate on calcium carbonate and metal surfaces. Little or no experimental data or other evidence is presented concerning the nature and extent of adsorption and the particular effect such adsorption confers when polyphosphates are adsorbed, in contrast to other classes of phosphates and organic compounds which may also be adsorbed on calcium carbonate or metal surfaces.

It is the objective of this paper to present data concerning the adsorption of polyphosphates on calcium carbonate surfaces and to show that these polyphosphates confer certain specific characteristics on calcium carbonate systems, which accounts for the observed threshold action.

A summary of the more recent investigations concerning the nature and structure of this class of phosphates will facilitate the interpretation of the data and discussion to be presented. The term "polyphosphate" is reserved for that class of phosphates produced by molecular dehydration of orthophosphates at high temperatures. Substances such as the pyropolyphosphates and tripolyphosphates are excluded because they are definite molecular compounds with distinct crystalline structures, although they may have the repeated —P—O—P— linkages which characterize the polyphosphate units. Polyphosphates are linear long-chain polyelectrolytes, and, on solution, produce large linear multicharged anions (*3–6*).

Methods

Two general procedures were adopted to obtain the data necessary for meeting the objectives of the project described here.* The first involves the measurement of phosphate adsorption

* The trade names and manufacturers of chemical substances used in this research were: Atomite (calcium carbonate), Thompson, Weinman and Company, Cartersville, Ga.; Purcal U (calcium carbonate), Wyandotte Chemicals Corp., Wyandotte, Mich; Triton-K-60 (a cationic wetting agent), Rohm and Haas, Philadelphia, Pa.; Arasket (an anionic wetting agent), Monsanto Chemical Company, St. Louis, Mo.; Nonisol 210 (a nonionic wetting agent), Alrose Chemical Company, Cranston, R.I.; Aquarex (lauryl mono ester of sulfuric acid), du Pont de Nemours and Company, Wilmington, Del.; Calgon (sodium hexametaphosphate), Hall Laboratories, Inc., Pittsburgh, Pa.; silicas and precipitated silicas, Columbia-Southern Chemical Corporation, Pittsburgh, Pa.; and sodium tripolyphosphate, Blockson Chemical Company, Joliet, Ill.

on two calcium carbonate samples of known surface area per unit weight. The second series of experiments concerns the effect of adsorption on individual calcium carbonate particles by the measurement of the electrophoretic mobility of these particles. A knowledge of the nature and extent of adsorption and the subsequent effect on the nature of the surface of calcium carbonate particles is thus gained. The electrophoretic mobility measurement gives information concerning the net electrical charge on individual calcium carbonate particles, which, in turn, is related to the zeta potential of the particles. The zeta potential characterizes the electric and diffusion layers surrounding each particle (*7*). Similar measurements were also made on silica particles of different surface area to extend the evidence presented for the proposed threshold action.

TABLE 1

Surface Areas and Particle Sizes of Samples Used

Item	Surface Area *sq m per g*	Estimated Particle Diameter From Electron Microscope Pictures—Å
Silica I	44	800–1,000
Silica II	117	250– 300
Silica III	225	150– 200
Purcal U	20	
Atomite	3	

Surface Area Measurements

The surface areas of the two calcium carbonate and three silica samples used in this work were determined by the nitrogen adsorption method. This work was done by Peter Vincenski of the Columbia-Southern Chemical Corporation, Barbertown, Ohio, in his laboratory which is specifically designed for this type of measurement. Preparation of the silica samples consisted of grinding the samples, suspending them in water, adjusting the pH value with HCl until constant pH values were obtained, filtering, and washing. A stock 0.16 per cent solution was then diluted with water to 0.04 per cent. Samples obtained by evaporating the water from these suspensions were used for the area measurement. The same stock suspensions were employed in subsequent electrophoretic measurements. The area determinations on the calcium carbonate samples were made from 0.1 per cent suspensions by drying off the water. Data are tabulated in Table 1, which includes results of diameter estimates of the silica particles from electron microscope pictures made only on the silica samples.

TABLE 2

Electrophoretic Mobility of Silica Particles in Trisodium Phosphate Solutions

Silica	Trisodium Phosphate *ppm*	Mobility 10^{-4} *cm/sec/v/cm*
I	0.0	−5.84
	1.0	−5.77
	10.0	−6.04
	100.0	−6.66
	500.0	−6.59
II	0.0	−5.94
	0.5	−6.89
	1.0	−6.93
	5.0	−7.17
	10.0	−7.00
	50.0	−7.30
	100.0	−6.48
	500.0	−6.31

Adsorption of Phosphates

Samples of solid calcium carbonate were weighed to 0.001 g. Different weights, from 0.2 to 3.0 g, were placed in 2-liter beakers. One liter of prepared solution from which adsorption was to take place was mixed with the

calcium carbonate. These mixtures were then allowed to stand for 48 hr, restirred, and allowed to settle, and the supernatant solution was taken for analysis. In some experiments, constant weights of calcium carbonate at 1 g were mixed with solutions of varying phosphate composition and similarly treated. Four samples were run for any given mixture so that reproducibility could be carefully checked.

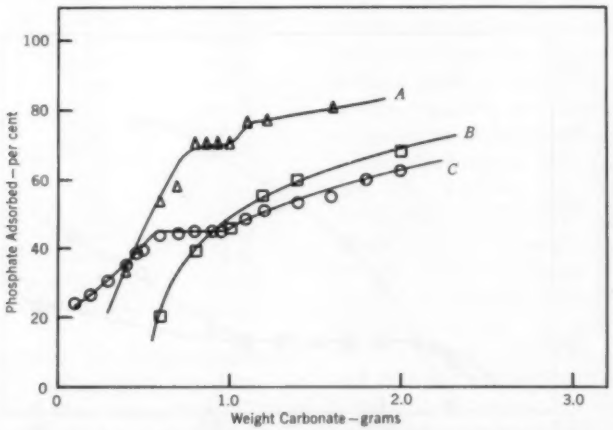


Fig. 1. Adsorption of Hexametaphosphate on Calcium Carbonate at Various Concentrations

The data shown are for adsorption from sodium hexametaphosphate at various initial concentrations, on 2.7 sq m per gram of calcium carbonate. Curves shown are for samples of the following concentrations: Curve A—*5 ppm; Curve* B—*2 ppm; and Curve* C—*10 ppm.*

Excellent duplication of results could be obtained in almost every set of four runs.

Analysis of phosphate from the solutions after adsorption was done colorimetrically because the total phosphate in solution never exceeded 10 ppm. This procedure involves measurement of orthophosphate ion, and therefore the conversion of polyphosphate to orthophosphate is required. A colorimeter * was used with a No. 62 filter, giving a calibration curve with orthophosphate standards which was linear up to 2 ppm orthophosphate ion. The correction for incomplete conversion of hexametaphosphate to orthophosphate was accomplished by running 10-ppm solutions of sodium hexametaphosphate with calcium carbonate mixtures. In other words, these blank solutions were allowed to stand for the same period of time as the test solutions and treated in exactly the same way. The 10-ppm solution of sodium hexametaphosphate, in terms of orthophosphate ion, was made from freshly prepared solutions containing 1.0760 g per liter of sodium hexametaphosphate, based on the reported P_2O_5 content of that material. Ten milliliters of each solution, including the sodium hexametaphosphate blank, were diluted to 50 ml with water. The solutions were boiled on a hot plate for exactly $\frac{1}{2}$ hr after adding 1 ml of 1:1 hydrochloric acid. They were

* A Klett-Summerson colorimeter, product of Klett Mfg. Co., New York, N.Y., was used.

quickly cooled and the excess acid was neutralized with sodium hydroxide to a phenolphthalein pink color. They were then diluted back to 50 ml. Two orthophosphate standards of 1 ppm each were prepared from an orthophosphate solution containing 0.05 mg per milliliter of orthophosphate ion. Potassium acid phosphate was used for the standard. The stannous chloride used to reduce the molybdate phosphate complex was a 0.6 per cent solution of stannous chloride in 1:1 hydrochloric acid. The ammonium molybdate solution contained 4 g of ammonium molybdate and 250 ml of concentrated sulfuric acid, and it was made up to 1 liter with water. The 50-ml samples were treated with 2 ml of ammonium molybdate solution and 1 ml of stannous chloride and allowed to stand 5 min. The colors produced on the two orthophosphate standards, the sodium hexametaphosphate solution, and the test solutions were then measured with colorimeter. The phosphate remaining in the test solutions, in terms of sodium hexametaphosphate, was then calculated as a fraction of the standard phosphate reading multiplied by the reading with sodium hexametaphosphate solution.

The adsorption data are illustrated in Fig. 1–5. In all but Fig. 5 the data are plotted showing percentage phosphate adsorbed versus weight of calcium carbonate. Figure 5 shows a plot of data obtained with constant weights of calcium carbonate at 1 g against residual phosphate concentrations from initial solutions of varying phosphate concentrations. The typical log-log plots for adsorption obeying the empirical Fruendlich equation are shown in Fig. 5. Note that the slopes are the same for the adsorption on calcium carbonate of two surface areas. The extrapolations of log k values give the value of x/m at residual phosphate concentrations of 1 ppm. The Freundlich

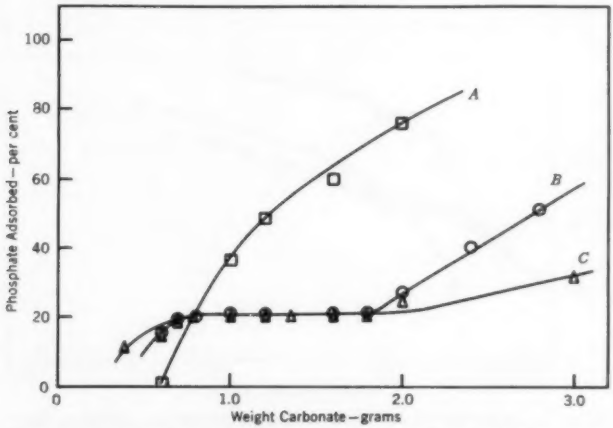


Fig. 2. Adsorption of Hexametaphosphate on Calcium Carbonate From Various Initial Phosphate Concentrations

The data shown are for adsorption on 20.4 sq m per gram of calcium carbonate. Curves shown are for samples of the following concentrations: Curve A*—5 ppm; Curve* B*—2 ppm; and Curve C—10 ppm.*

TABLE 3

Electrophoretic Mobility of Silica Particles in Sodium Hexametaphosphate Solutions

Silica	Hexametaphosphate ppm	Mobility 10^{-4} cm/sec/v/cm
I	0.0	−5.84
	1.0	−6.11
	10.0	−7.37
	100.0	−7.03
	500.0	−7.44
II	0.0	−5.90
	0.5	−7.20
	1.0	−8.02
	5.0	−8.60
	10.0	−9.49
	50.0	−8.23
	100.0	−8.36
	500.0	−7.00
III	0.0	−6.14
	1.0	−6.78
	10.0	−6.55
	100.0	−6.38
	500.0	−5.60

equation, $x/m = kC^n$, is typical of many adsorption results, both for gases on solids and for adsorption from solution by solids. In this equation C is the residual or equilibrium concentration remaining in solution after adsorption, n and k are typical constants, and x/m is the amount adsorbed per gram or unit weight of solid.

Figure 3 shows the adsorption of sodium tripolyphosphate, and Fig. 4 shows the effect of the presence of 10 ppm anionic wetting agent on the adsorption of polyphosphates from 5- and 10-ppm phosphate solutions.

Electrophoretic Mobility Measurements

The electrophoretic mobilities were measured by the microscopic method * (*8*). The essential features of this method result from the ability to view individual particles through the microscope against a dark-field illumination, and to measure the horizontal velocity of particles directly. Figure 6 shows a line drawing of the apparatus. A flat cell, $4.05 \times 1.5 \times 0.0636$ cm, is fitted with sealed-in platinum electrodes. These electrodes communicate to zinc in zinc sulfate solution electrode systems. A potential difference of 45 v is applied across the electrode system so that charged particles, placed in the cell in liquid suspension, will move with a velocity dependent on the net charge and double layer condition of the individual particle (*9*).

A microscope with a 10× objective, a 12.5 filar eyepiece, and a fitted

* Equipment used was a product of The Arthur H. Thomas Co., Philadelphia, Pa.

TABLE 4

Electrophoretic Mobility of Calcium Carbonate in Lanthanum Nitrate Solutions Containing Sodium Hexametaphosphate*

$La(NO_3)_3$ ppm	Mobility—10^{-4} cm/sec/v/cm			
	No Hexametaphosphate	2 ppm Hexametaphosphate	5 ppm Hexametaphosphate	10 ppm Hexametaphosphate
0.0	−1.59	−3.99	−4.33	−4.74
1.0	−2.34	−3.30	−3.40	−3.86
10.0	−2.55	−2.38	−3.62	−4.27
50.0	+1.50	0	−0.80	−1.11
100.0	+3.36	+1.70	+1.72	+1.75

* Atomite was used, which has a relatively low surface area per gram of weight.

calibrated scale makes it possible to view individual particles against a dark-field illumination provided by fixing a cardioid condenser at the bottom of the cell. Suspensions of the particles enter the cell as needed through reservoirs connected to the cell. When a series of measurements is to be made, the prepared solution is allowed to enter the cell. The focus is adjusted to exactly 21.1 per cent of the vertical depth of the cell, because no interference from liquid motion is obtained at this level. Individual particles singled out for observation may be followed as they move horizontally. The speed is recorded in centimeters per second. The motion of one particle may be studied, or several particles, one at a time, may be viewed. The results reported are the average of results on several particles and for at least four horizontal motions back and forth for each particle under the same potential difference. When and if coagulation takes place, the effect may be viewed directly as individual particles come together. The reverse effect, namely redispersion, may also be viewed directly, because agglomerates may be seen to break up into individual particles. These details are presented here because the method should prove a valuable tool to the water chemist interested in the study of the coagulation of particular systems.

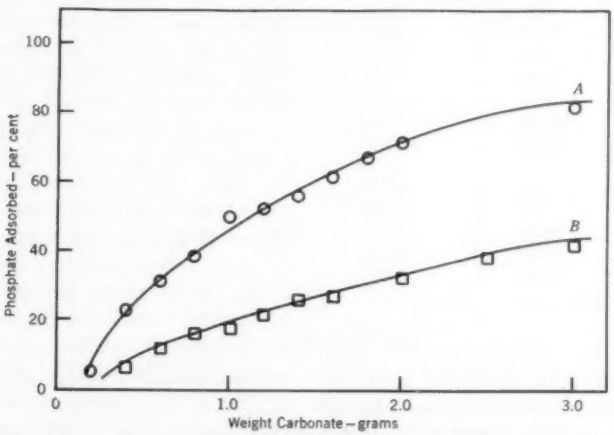


Fig. 3. Adsorption of Sodium Tripolyphosphate on Calcium Carbonate From 10-ppm Initial Phosphate Solution

Curve A *is for a surface area of 20.4 sq m per gram of calcium carbonate, and Curve* B *for a surface area of 2.7 sq m per gram of calcium carbonate.*

Suspensions of silica were prepared from the stock solutions used for area measurements as previously described. The addition of phosphates and other agents was always made ½ hr prior to the actual study of the motion, and 0.1 per cent suspensions of calcium carbonate were used in the electrophoretic measurements. The data from the mobility measurements are summarized in Tables 2–14.

Mobilities are given plus or minus values, the latter referring to particles

TABLE 5

Electrophoretic Mobility of Calcium Carbonate in Lanthanum Nitrate Solutions Containing Sodium Hexametaphosphate*

$La(NO_3)_3$ ppm	Mobility—10^{-4} cm/sec/v/cm			
	No Hexametaphosphate	2 ppm Hexametaphosphate	5 ppm Hexametaphosphate	10 ppm Hexametaphosphate
0.0	−1.09	−2.62	−2.92	−2.89
0.5	−0.93			
1.0		−2.54	−2.87	−3.16
5.0	−1.53			
10.0		−2.84	−3.04	−3.13
50.0	−1.61	−2.10	−2.60	−2.92
100.0	−1.09	−1.80	−2.16	−2.60
200.0	+2.30			
250.0		+0.85	+0.61	+0.34
300.0	+2.44			
500.0	+2.98	+1.73	+1.57	+0.68

* Purcal U was used, which has a relatively high surface area per gram of weight.

moving toward the anode, and hence negatively charged. The former are positively charged particles. The values of mobilities are used for relative comparison rather than for the calculation of zeta potentials. The zeta potential, however, is directly proportional to the mobility (*9*) when reported in centimeter per second per volt per centimeter.

Discussion

This discussion is not concerned with showing that glassy phosphates or polyphosphates can help in the prevention of calcium carbonate deposits. The present article is intended, rather, to indicate a mechanism by which these phosphates produce the desired action. The data given must, therefore, present evidence for the specific properties conferred by polyphosphates which other substances do not make evident, and give some definite reason for the limited dosage range within which polyphosphates produce their action or which characterizes threshold action in practice.

The deposition of calcium carbonate takes place on surfaces through which heat is transferred to the water producing the deposit or from the water to external surroundings. Scale, therefore, may form on condenser tube surfaces, where the heat transfer is into the water from the surface, or, in hot-water piping or feedlines, where the heat transfer is in the opposite direction. Deposition from waters saturated with calcium carbonate, such as those

TABLE 6

Electrophoretic Mobility of Calcium Carbonate in Magnesium Chloride Solutions Containing Sodium Hexametaphosphate*

$MgCl_2$ ppm	Mobility—10^{-4} cm/sec/v/cm	
	No Hexametaphosphate	5 ppm Hexametaphosphate
0.0	−1.09	−2.92
5.0	−0.34	
10.0	−0.34	−2.07
63.0	0	−2.95
310.0	+1.24	−2.03
500.0	+1.59	−1.20

* Purcal U was used, which has a relatively high surface area per gram of weight.

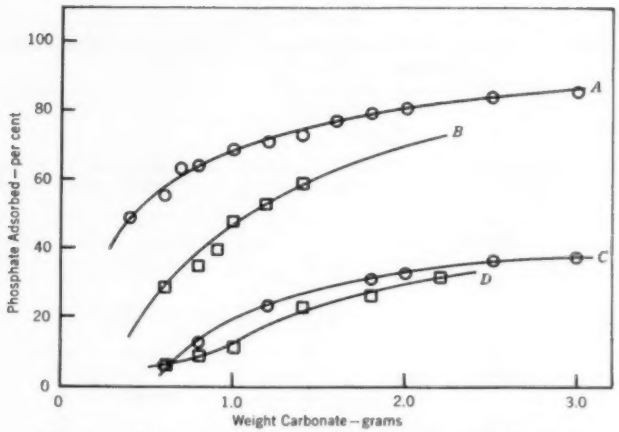


Fig. 4. Adsorption of Sodium Hexametaphosphate With 10 ppm Anionic Wetting Agent

The adsorption was from 10 ppm initial phosphate concentration. Curves A *and* C *are for 10-ppm solutions; Curves* B *and* D *for 5-ppm solutions. Curves* A *and* B *are for surface areas of 20.4 sq m per gram of calcium carbonate and Curves* C *and* D *are for surface areas of 2.7 sq m per gram of calcium carbonate.*

treated with lime, is well known. It is obvious, therefore, that the first requirement for deposition is that the water should attain calcium carbonate saturation at the surface water interface over which water is flowing. A number of factors, such as solubility–salt concentration coefficients along with solubility–temperature coefficients, may influence the saturation concentration. The work of Langelier (*10*), Larson and Buswell (*11*), and others provides considerable data on these subjects. When saturation is reached, growth, rather than deposition, of calcium carbonate accounts for scale formation. In other words, crystalline growth on calcitic surfaces in contact with saturated or near-saturated solutions proceeds through the orientation of microscopic calcium carbonate nuclei as they form from solution or from the diffusion of carbonate and calcium ions on the surface initially formed by the first adsorption of calcium carbonate on surfaces over which water flows. It is not unusual to find piping almost completely filled with dense, hard, crystalline deposits of calcium carbonate in

TABLE 7

Electrophoretic Mobility of Calcium Carbonate in Magnesium Chloride Solutions Containing Sodium Hexametaphosphate*

$MgCl_2$ *ppm*	Mobility—10^{-4} *cm/sec/v/cm*	
	No Hexametaphosphate	5 ppm Hexametaphosphate
0.0	−1.59	−4.33
5.0	+0.34	
10.0	+0.34	−2.65
63.0	+0.89	−2.89
310.0	+1.69	−2.16
500.0	+1.64	−1.27

* Atomite was used, which has a relatively low surface area per gram of weight.

areas where heat transfer obviously does not play a part in deposition, although, at one time, this transfer may have been important in initiating the first deposition or adsorption of calcium carbonate on the surface.

The action which prevents deposition or growth of calcium carbonate must involve factors which impede the regular orientation of calcium carbonate nuclei, extend the saturation concentration of calcium carbonate, or colloidally disperse calcitic precipitation as it forms. Whatever this action may be, it must operate at the point of transition of calcium carbonate in solution to calcium carbonate in a solid state. Von Weirman and Nernst-Noyes (*12*) proposed mathematical expressions which concern the nature of the precipitated substances on formation from solution. The first expression is:

$$W = K\frac{C - L}{L} = KN$$

in which W represents the speed at which nuclei form from solution, C is the total amount of substance available for precipitation, L is its solubility in its normal, coarse, crystalline state, and K is a constant dependent on the substance. The absolute supersaturation is $C - L$, and $\frac{C - L}{L}$ is the degree of supersaturation. If the latter is large, because L is small, the rate of nuclei formation is high and colloidal-like precipitation may occur. If L is moderately large, the rate of nuclei formation may be slow. This appears true with calcium carbonate and for other substances tending to precipitate slowly to form crystalline aggregates.

The second expression concerns the rate of growth of crystalline surfaces after the nuclei have formed. This is given by:

$$V = KSD\frac{C - L}{T}$$

where V is the velocity of surface growth, $C - L$ the supersaturation, as in the first expression, S the surface area per particle, T the thickness of the layer surrounding the particle which influences diffusion of ions into the surface of the particle, and D the diffusion coefficient. In the latter expression, it would appear that if S is small and T is relatively large the crystalline growth would be slowed considerably. Thus it is probable that, when T is a predominant factor, the complete disruption of crystal growth is effected because nuclei orientation is prevented or diffusion of ions for growth is completely inhibited or greatly slowed. It should be noted that microscopic nuclei of calcium carbonate just precipitating from solution will probably have large ratios of surface area to particle size, although the surface area per particle may be quite small.

TABLE 8

Electrophoretic Mobility of Silica II Particles in Sodium Sulfate Solutions

Na_2SO_4 *ppm*	Mobility 10^{-4} *cm/sec/v/cm*
0.0	−6.07
0.5	−6.18
1.0	−6.83
3.0	−7.30
5.0	−7.13
10.0	−6.69
30.0	−6.38
50.0	−5.80
100.0	−5.70
500.0	−4.47

The data the authors have obtained show that phosphates are adsorbed on calcium carbonate surfaces. The amount and nature of adsorption depends, among other things, on the surface area per unit weight of the cal-

cium carbonate and the initial concentration of the solution from which adsorption is to take place. The mobility data show that the nature of the surface of calcium carbonate particles is altered to the extent that the factor T is sufficiently increased to account for the disruption of crystal growth.

It should be emphasized that a surface area measurement by gas adsorption on dry samples may not give the true measure of surface area of the same substance when suspended in aqueous media. Some understanding of the relative surface area of the samples is necessary, however, and, because the number of particles produced by a given weight of substance should be proportional to the cube of the area per gram of the substance, it can be seen that the number of particles presented by the high-surface-area substance, compared to that given by the low-area sample, will stand in a ratio of about 100 to 1, even should some agglomeration or clustering of particles take place in aqueous suspension.

Thus, while only two samples of different surface areas are involved in the measurements, some idea of the trend of the phenomena under observation relative to the effect of area will be gained.

In the experiments discussed here, information as to the effect of adsorption when calcium carbonate nuclei were first formed in the transition from solution to the solid state was sought. It may be assumed that the particles first formed will have high ratios of area to particle size, and that the area per particle will be small.

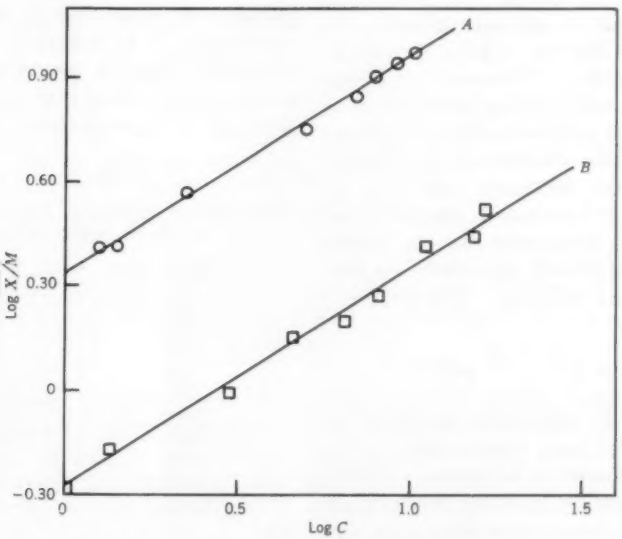


Fig. 5. Log-Log Plot of Adsorption Data According to Freundlich

Line A *is from data for a surface area of 20.4 sq m per gram of calcium carbonate. Line* B *is from data for a surface area of 2.7 sq m per gram of calcium carbonate.*

Also, the weight per liter of such particles on first precipitation will be quite small.

The adsorption from 2 ppm hexametaphosphate solution (*see* Fig. 1 and 2) shows that the first measurable adsorption requires a lower weight of the high-surface-area sample of calcium carbonate, but that thereafter the amounts adsorbed by the two calcium carbonate samples follow the same general trend. Adsorption from 5- and 10-ppm hexametaphosphate solutions produces regions of constant adsorption, as indicated by the flat portions of the adsorption plot. Adsorption of phosphate, in parts per million, and the

TABLE 9

Electrophoretic Mobility of Silica II Particles in Sodium Carbonate Solutions

Na_2CO_3 *ppm*	Mobility 10^{-4} *cm/sec/v/cm*
0.0	−5.57
0.5	−5.60
1.0	−5.46
3.0	−5.84
5.0	−5.53
7.0	−5.49
10.0	−5.43
30.0	−5.43
50.0	−5.36
100.0	−5.63
500.0	−5.67

percentage removal are higher with the high-surface-area calcium carbonates. Further, it will be noted that the extent of the flat portion of the curves is smaller for the high-surface-area sample, but is absent at lower initial phosphate concentrations. The weights of calcium carbonate which showed initial measurable adsorption were significantly different for the low- and high-area calcium carbonates. Thus, 0.6 g of low-area sample showed no adsorption, but the same weight of high-area sample showed 0.4 ppm adsorbed from the 2-ppm solutions of hexametaphosphate. From 5-ppm hexametaphosphate solutions 0.2 g is required to accomplish the same extent of adsorption as 0.4 g of low-area carbonate. It may be concluded that both the initial concentration of phosphate and the area of the sample doing the adsorbing are determining factors for the extent of adsorption which may take place. This high area per unit weight is the compatible situation for calcium carbonate nuclei just coming out of solution.

TABLE 10

Electrophoretic Mobility of Silica Particles in Calcium Chloride Solutions

Silica	$CaCl_2$ *ppm*	Mobility 10^{-4} *cm/sec/v/cm*
I	0.0	−6.04
	0.5	−5.43
	5.0	−3.75
	50.0	−3.17
	500.0	−2.60
II	0.0	−6.07
	0.5	−4.57
	1.0	−4.20
	3.0	−3.69
	5.0	−3.45
	7.0	−3.29
	10.0	−2.95
	30.0	−3.02
	50.0	−2.92
	100.0	−2.38
	500.0	−2.18
III	0.0	−6.14
	1.0	−3.97
	10.0	−2.92
	100.0	−2.60
	500.0	−2.26

The horizontal portions of the plots shown in Fig. 1 and 2 suggest that agglomeration of calcium carbonate is induced by the presence of phosphate in solution. The horizontal plot covers a greater weight range of the low-area carbonate, and, because the number of

particles made available from this sample is much less than for the higher-area sample, it appears feasible to conclude that the flat plots result from agglomeration, and that the added weight of calcium carbonate sample, instead of increasing the area for phosphate adsorption, provides an approximately constant area because of the loss of surface due to agglomeration. The agglomeration probably takes place through calcium-phosphate linkages. When samples were withdrawn from the test beakers with the fingers, these samples were threadlike in structure and as long as 12 in. The strong calcium-phosphate bonding from poly anions supplied by the hexametaphosphate probably favors one particular face of the crystalline calcium carbonate particles, leading to the string formations which were observed. Some adsorption must have preceded agglomeration even though the experimental samples were allowed to stand for some time. Other evidence for the strong agglomerating tendencies of the glassy phosphate is shown by Fig. 7. The ropelike structure shown is the result of small amounts of gel-like substance formed from a 1,000-ppm hexametaphosphate solution which was allowed to stand for several weeks.

The suggestion that wetting agents may enhance the ability of polyphosphates to inhibit calcium deposits prompted the trial of the adsorption in the presence of 10 ppm of anionic wetting agent (*see* Fig. 4). The flat portions, which characterize the adsorption plots for the same weights of calcium carbonate and phosphate concentration, are absent. This suggests an added dispersent action from wetting agents. But mobility data indicate that the overall nature of the surface is only slightly changed from that produced by the addition of phosphate alone. It is possible that the presence of anionic agents or strongly adsorbed

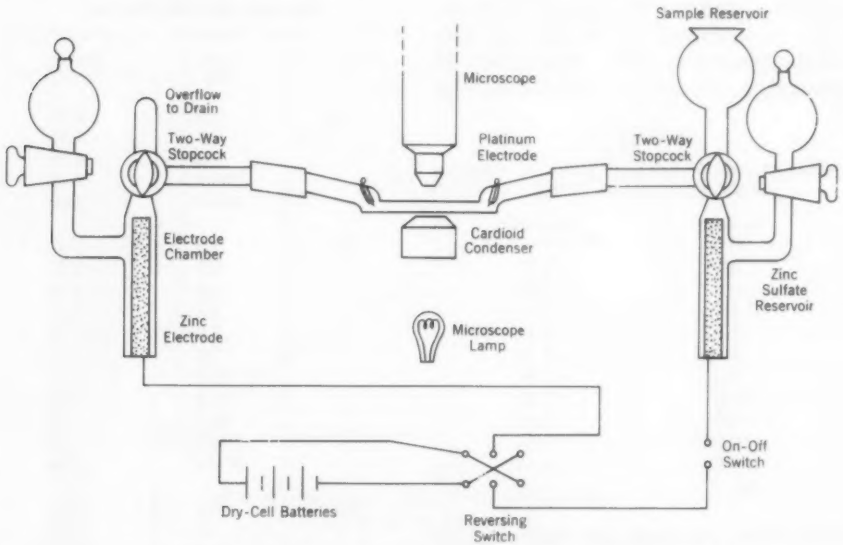


Fig. 6. Apparatus for Electrophoretic Mobility Measurements

organic compounds of large molecular size might extend the range of dosage which gives results in practice, but all the present data indicate that low phosphate dosages favor the best results and this is largely supported by the mobility data, which will be discussed.

The adsorption of tripolyphosphate, as shown in Fig. 3, clearly demonstrates that adsorption is not restricted to glassy phosphates. The long-chain poly anions made available by the phosphates of the hexametaphosphate class, however, should change the crystalline surface on which they are adsorbed by increasing the diffusion layer thickness to the extent that further crystalline growth is prevented. The adsorption of crystalline-like phosphates, however, does not necessarily indicate that crystalline growth should stop. Therefore, although a variety of phosphates may be adsorbed on calcium carbonate surfaces, only those conferring colloidal-like characteristics should be expected to disrupt normal crystal growth of calcium carbonate surfaces.

The changes in electrophoretic mobility produced by adsorbed phosphates on silicas of three different surface areas are noted in Tables 2 and 3. Even at 10 ppm of orthophosphate ion, the increase in negative mobilities is very small and remains fairly constant as more and more phosphate is added. But 1.0 ppm of hexametaphosphate produces the same change as does 10 ppm of trisodium phosphate, and the negative mobility increase resulting from higher hexametaphosphate additions is quite significant.

Tables 4 and 5 give the complete mobility information on the effect of hexametaphosphate on the two calcium carbonate samples employed in this work. The addition of lanthanum nitrate is one means of adding a trivalent cation which counteracts the negative charge on the calcium carbonate particles. The amount of lanthanum used, therefore, is a relative measure of charge accumulated on calcium carbonate particles. Several conclusive and interesting facts are brought out by this data.

The mobility of calcium carbonate particles, with no other added agent present, is negative. Calcium carbonate particles, therefore, are slightly negatively charged. Particles like silica, however, are highly negatively charged. The negative charge on the smaller particle—that is, the particles with a greater area per gram—is smaller than on the low-area particles; the mobilities are −1.09 and −1.59, respectively. It should be noted that the mobilities of silica particles are about −6.0 for all surface area samples. The addition of 2 ppm of hexa-

TABLE 11

Electrophoretic Mobility of Silica Particles in Aluminum Chloride Solutions

Silica	$AlCl_3$ *ppm*	Mobility 10^{-4} *cm/sec/v/cm*
I	0.0	−6.18
	5.0	0
	50.0	+3.36
	500.0	+4.54
II	0.0	−6.04
	0.5	−4.95
	1.0	−4.30
	3.0	−2.02
	5.0	−0.78
	7.0	0
	10.0	+0.74
	30.0	+1.85
	100.0	+2.80
	500.0	+3.89
III	0.0	−6.14
	1.0	−4.71
	10.0	0
	100.0	+2.27

metaphosphate causes an increase in negative mobility to −2.62 for the high-area calcium carbonate, and −3.99 for the low-area particles, or a net increase in negative mobility of −1.53 and −2.40, respectively. Greater additions of hexametaphosphate cause further increases which are either very small or nonexistent. The greatest effect, therefore, is from small additions of phosphate. The effect of the added trivalent ion to calcium carbonate particles after phosphate adsorption should be noted. Although approximately 5 ppm of lanthanum ion is needed to cause reduction or reversal in charge on low-area calcium carbonate, it requires about five times this lanthanum concentration to produce similar effects on the high-area calcium carbonate, but the mobility and negative charge per particle of low-area calcium carbonate are initially almost twice that for the high-area calcium carbonate. Again, the fact that there are many more high-area calcium carbonate particles present should be emphasized. Care must be taken to distinguish between total area per unit weight of substance and area per particle of the same substance in suspension.

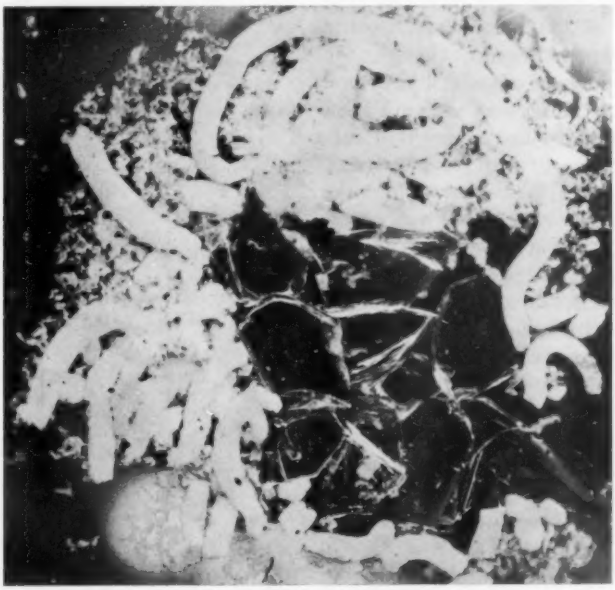


Fig. 7. Phosphate Agglomerates

The first gel-like precipitates form agglomerates, such as those shown here, after standing for several weeks.

In the experiments discussed here, two commercial brands of calcium carbonate were used.* Brand 1 had a high area per gram compared to Brand 2. In aqueous suspension, therefore, Brand 1 should produce a much larger number of particles, each of which may have a smaller area than particles of Brand 2. The increase in mobility

* Brand 1 was Purcal U; Brand 2 was Atomite.

caused by hexametaphosphate may therefore be expected to be larger. But an increase in mobility is an increase in the thickness of the double layer surrounding the particle, and the particles of Brand 2 calcium carbonate accumulate a thicker double layer than is produced on Brand 1. It is the relationship between the size of the double layer produced and the initial particle size which is important here, however, and, even though the double layer on Brand 1 is not as thick as that on Brand 2, the ratio of double layer to particle size is much larger. As the particle size becomes smaller, this ratio becomes larger. In the limiting case for calcium carbonate nuclei just coming out of the saturated solution, the effect of adsorption and the creation of a double layer may be expected to solubilize the particle by keeping it ultramicroscopically small. The phosphate, therefore, keeps nuclei separated as they form, prevents crystalline orientation, and extends the saturation concentration by the solubilizing effect described.

Because natural water supplies usually contain calcium and magnesium salts as well as chloride and sulfate ions, the effect of these ions was studied on silica particles as well as on calcium carbonate particles in suspension. Tables 6 and 7 show the effect of the presence of magnesium ion on the mobilities of calcium carbonate particles. Although it requires only 5 ppm of magnesium ion to cause coagulation of calcium carbonate without hexametaphosphate present, no amount of magnesium up to 500 ppm causes reversal in charge or coagulation of calcium carbonate particles on which some hexametaphosphate is adsorbed.

It is also interesting to note that although 5 ppm of magnesium ion causes coagulation or reversal of charge on Brand 2 calcium carbonate particles, it requires up to 60 ppm of magnesium ion to produce the same effect on Brand 1 calcium carbonate particles. Table 8 shows the effect of sulfate ion on silica particles. No significant changes occur when sulfate ion is present in solution. Table 9 shows that sodium carbonate, even with high pH values, produces no significant effects on mobilities of silica particles. Table 10 gives results with the use of calcium chloride, and it is interesting to note that even concentrations of 500 ppm produce no significant changes in mobilities. Divalent ions, therefore, except for magnesium, produce no significant effects on silica or calcium carbonate suspensions. The effect of

TABLE 12

*Electrophoretic Mobility of Silica Particles With Cationic Wetting Agent**

Silica	Wetting Agent *ppm*	Mobility 10^{-4} *cm/sec/v/cm*
I	0.0	− 6.00
	0.5	− 5.72
	1.0	− 4.39
	3.0	+ 2.32
	5.0	+ 3.09
	10.0	+ 6.35
	50.0	+10.3
	100.0	+10.7
	500.0	+10.0
II	0.0	− 6.19
	0.5	− 6.11
	1.0	− 6.62
	5.0	− 3.92
	10.0	0
	50.0	+ 7.20
	100.0	+ 7.17
	500.0	+ 8.09
III	0.0	− 5.94
	1.0	− 5.90
	10.0	− 4.44
	100.0	+ 5.29
	500.0	+ 6.25

* The wetting agent used was Triton-K-60.

TABLE 13

*Electrophoretic Mobility of Silica II Particles With Anionic Wetting Agent**

Wetting Agent *ppm*	Mobility 10^{-4} *cm/sec/v/cm*
0.0	−6.21
0.5	−6.35
1.0	−6.35
5.0	−6.35
10.0	−6.45
50.0	−6.42
100.0	−6.31
500.0	−5.73

* The wetting agent used was Arasket 300.

small amounts of magnesium on calcium carbonate particles in the absence of adsorbed hexametaphosphate is important, however.

As might be expected, the effect of trivalent ions is a distinctive phenomenon. Reversal in charge is produced on silica with small additions of aluminum ions, and on calcium carbonate with additions of lanthanum ions. Table 11 shows that as little as 5 ppm of aluminum ions can cause reversal of charge. In all the tests observed, coagulation or the visible agglomeration of particles always occurs before actual reversal in charge takes place—that is, dosages less than the dosage required for the reversal of charge causes coagulation. Table 11 also shows that the amount of aluminum ion necessary to produce reversal of charge on the three silicas is on the order of 5, 7, and 10 ppm for the three silicas of increasing surface area. This again indicates that both the size of the particle and its net charge are factors which determine its stability.

The subject of the effect of wetting agents on the stability of colloidal systems is of interest in water chemistry. The effects of cationic, anionic, and nonionic agents on mobilities are therefore included in these studies.

Table 8 shows the rather remarkable effect of a cationic wetting agent on silica particle systems. This agent behaves as a strong polyvalent positive ion. Only 3 ppm is needed to produce reversal in charge on silica of low surface area, while 10 ppm is needed to produce the same effect on the highest-area silica. Nevertheless, these amounts are quite small. It will be noted, also, that additional amounts of this wetting agent produce an increase in positive charge and redispersal of the previously agglomerated particles. On the other hand, anionic agents and nonionic agents affect the mobilities but little on the initially negatively charged particles, as may be noted from the data in Tables 13 and 14.

The particular effect produced by cationic agents should be of interest to the water chemist interested in coagulation studies. The tendency for these substances to aggregate into groups or micelles produces the same effect as single large ions of high apparent charge and valence effect. Their possible use in conjunction with metal ions should be investigated.

Conclusions

Glassy phosphates of the hexametaphosphate class possess unique properties not manifested by other phosphates, although the latter may be readily adsorbed by calcium carbonate. The threshold action they produce appears to be largely dependent on their ability to be adsorbed from solutions of very low concentration and by low weights of calcium carbonate nuclei as they form from saturated calcium carbonate solutions. The tendency to inhibit precipitation is probably caused by the large ratio of double layer to particle size produced by adsorption. This effects the solution of calcium carbonate nuclei—at least the dispersion of ultramicroscopic crystals of calcium carbonate is, in effect, an extension of the saturation concentration of calcium carbonate. More important, perhaps,

TABLE 14

*Electrophoretic Mobility of Silica II Particles With Nonionic Wetting Agent**

Wetting Agent *ppm*	Mobility 10^{-4} *cm/sec/v/cm*
0.0	−5.84
0.5	−5.73
1.0	−5.60
5.0	−6.11
10.0	−6.07
50.0	−6.31
100.0	−6.07
500.0	−6.11

* The wetting agent used was Nonisol 210.

is the fact that regular grouping into larger crystal aggregates of calcium carbonate is prevented. When the initial concentration of hexametaphosphate is higher than 5 ppm, the tendency to cause agglomeration of nuclei is definitely indicated. The presence of anionic agents may prevent this action and thus extend the working dosages of added phosphate, but it is the phosphate in low concentrations which produces the desired action. From data collected on calcium carbonate with magnesium, it appears that the coagulating effect of magnesium salts is completely inhibited when phosphates are present. Magnesium salts in water become important to scale formation in the absence of phosphates, as is indicated by the way in which very small amounts of magnesium enhance coagulation of small particles of calcium carbonate. Because this salt remains in solution even at fairly high pH values, the growth of calcium carbonate onto larger aggregates is promoted.

Because polyphosphates tend to revert to orthophosphates with time and temperature, the presence of orthophosphate may prove detrimental. The loss of polyphosphate caused by hydration must also be considered. These factors are important in the treatment of water where higher temperatures may be attained. The temptation to raise polyphosphate dosage to compensate for loss resulting from hydration should be restrained because a dosage of 1–3 ppm will provide adequate treatment control if little or no conversion occurs. The residence time of water over surface is important, too, when effects of added phosphate are considered.

References

1. Reitmer, R. F. & Bueher, T. F. The Inhibiting Action of Minute Amounts of Sodium Hexametaphosphate on the Precipitation of Calcium Carbonate From Ammoniacal Solutions. II. *J. Phys. Chem.*, **44**:552 (1946).
2. Van Wazer, J. R. *Encyclopedia of Chemical Technology.* Vol. 10. Interscience Publishers, Inc., New York.
3. Van Wazer, J. R. Structure of Condensed Phosphates. II. A Theory of Molecular Structure of Sodium Phosphate Glasses. *J. ACS*, **72**:644 (1950).
4. Van Wazer, J. R. Structure of Condensed Phosphates. V. Molecular Weights of The Polyphosphates From Viscosity Data. *J. ACS*, **72**:906 (1950).
5. Van Wazer, J. R. Structure and Properties of Condensed Phosphates. IV. Complex Ion Formation in Polyphosphate Solutions. *J. ACS*, **72**:655 (1950).
6. Straus, U. P. & Smith, E. P. Polyphosphate as Poly Electrolytes. II. *J. ACS*, **75**:6186 (1953).
7. Gouy, G. J. *J. Phys.*, **9**:457 (1910).
8. Northrup, J. H. A Microscopic Method for Measuring Electrophonetic Mobility. *J. Gen. Physiol.*, **7**:729 (1925).
9. Smolochowcki, M. *Graetz Handbuch der Elektrizität und des Magnitismus.* Vol. 11 (1914).
10. Langelier, W. F. The Analytical Control of Anticorrosion Water Treatment. *Jour. AWWA*, **28**:1500 (Oct. 1936).
11. Larson, T. E. & Buswell, A. M. Calcium Carbonate Saturation Index and Alkalinity Interpretations. *Jour. AWWA*, **34**:1667 (Nov. 1942).
12. Weiser, H. B. *Colloid Chemistry.* John Wiley & Sons, New York (2nd ed., 1949). p. 136.

Estimation of Flow-Through Time by the Continuous-Dose Method

Michael J. Taras

A contribution to the Journal by Michael J. Taras, Research San. Chemist, Dept. of Water Supply, Detroit, Mich.

NEAR the turn of the century two methods were proposed for determining the velocity of flow through filter media. The first of these originated about 1890 at the Lawrence Experiment Station of the Massachusetts State Board of Health (*1*). This method depended on the continuous displacement of a solution of known chloride concentration by a solution with a different chloride concentration. The flow-through time was assumed to be the overall interval required for the second chloride concentration to materialize fully in the effluent.

The second method, advanced by Clifford in 1907 (*2*), called for the addition of a momentary high dose of chloride to the influent and the observation of the chloride's appearance and disappearance in the effluent. Clifford himself supplied the mathematical interpretation of the data which evolved from his experiments. Of the Lawrence method, he argued that the actual flow-through time was not the overall period involved in eliminating the added chloride from the effluent. If the chloride were properly applied to the influent, he reasoned, it would move in such a manner that a dilution of the chloride would appear in the forefront as well as in the vanguard of the effluent. Between the leading and trailing edge would move the greatest chloride concentration. Therefore, suggested Clifford, only the time representing the center of gravity of the added chloride concentration in the effluent was the true flow-through time.

Comparing his momentary-dose method with the Lawrence continuous-dose method, Clifford noted that his method yielded a consistently lower time than that afforded by the Lawrence method (*3*). At the same time, he recognized that when the Lawrence method was interpreted properly the two methods gave similar results. Clifford's interpretation of the continuous-dose data, however, was intuitive rather than mathematical. It is likely that the mathematical basis of the momentary-dose method explains its ascendancy through the years; by the same token, the fact that the continuous-dose method rested on an arbitrary and nonmathematical basis probably accounts for its fall from favor. At any rate, the continuous-dose method deserved a better fate.

Both the Clifford and Lawrence experiments were concerned solely with flow-through time in filters. Capen adapted Clifford's ideas to the determination of the flow-through time of a number of sewage settling tanks (*4*). To this day the Capen-Clifford approach remains the method of choice for estimating the efficiency of sedimentation basins. No critical evaluation has yet been undertaken of the relative

merits of the Lawrence method with regard to the flow-through time of sedimentation basins or large water tunnels.

The book *Water Quality and Treatment* describes in detail a modified version of the Capen method for determining the flow-through period of sedimentation basins (*5*). The procedure involves the addition of a batch of sodium chloride to the influent and the determination of the chloride concentration of the basin effluent at selected intervals. The resulting chloride levels of the effluent are plotted against the time of sample collection to yield a curve whose area can be computed by the method of moments for the center of gravity. The center of gravity is regarded as the flow-through period of the basin.

Morrill has aptly outlined the shortcomings of the momentary-dose method (*6*). Unless the concentrated salt solution is speedily and uniformly distributed into the entering flow, the density of the brine may cause the settling of a portion of the salt in the basin. Thereafter, chloride may persist in the effluent for many hours after it should have disappeared, due to the gradual diffusion of the salt layer into the main stream of the basin. Inasmuch as equivalent ammonium chloride solutions are less dense than those prepared from common salt, Morrill preferred the ammonium compound for his basin tests. The use of ammonium agents in the current era of free residual chlorination, however, might be objected to by many.

The factors enumerated by Morrill apply equally to many chemical reagents which might be considered for a basin study. The chemical and physical behavior of the reagent—such as the degree of deposition or adsorption on the various surfaces involved—plays an important part in the final results of the story. Any time a nontreatment chemical is employed for a basin survey, careful attention must be accorded to the possible eccentricities of the compound; otherwise, the investigation may confirm the deficiency of the added chemical rather than reflect basin efficiency.

When reliance is placed upon the momentary-dose method, the importance of uniform introduction of the chemical to the influent basin water cannot be exaggerated. Since a concentrated solution often has a greater density than the inflowing water the anticipated ideal performance might not be achieved even in an ideal basin. For best results, the identifying agent must be applied rapidly (in fact, instantaneously) in a thin layer penetrating a complete cross section of the basin entrance. The difficulty of achieving this condition in a moving body of water is obvious.

The momentary-dose method suffers one notable disadvantage when used in the study of large basins: the volume of salt solution required for a basin of 10-mil gal capacity is appreciable. The problem is magnified if the salt solution must be delivered within a period of several minutes. Needless to say, sufficient salt solution must be added so that a well-defined response can be demonstrated in the effluent of the basin. Basins of small and moderate size would seem to offer the greatest likelihood of success in the application of the momentary-dose method.

Experimental Details

The basins employed in checking the validity of the flow-through principles by both the continuous-dose and momentary-dose methods were constructed of common laboratory glassware. The entire system, illustrated in Fig. 1, was

based on the siphon principle, with 4- or 9-liter pyrex solution bottles constituting the interchangeable basins. An inlet tube, through which the water entered the basin, extended to within $\frac{1}{4}$ in. of the bottom of the bottle. The outlet tube was located in the neck of the rubber-stoppered bottle and was fitted with a rubber hose which terminated below the level of the bottle.

The rubber-stoppered 5-gal carboy, charged with the continuous-dose solution, was connected by means of glass and rubber tubing to a rubber-stoppered aspirator flask mounted in an elevated position. The elevated flask allowed some control of the rate at which the water was delivered to the basin. When the momentary dose was used, a T tube, inserted between the elevated flask and the inlet tube to the basin, admitted chemical solutions from a separatory funnel to the basin. In normal operation, the displacing solution was forced from the 5-gal carboy into the overhead flask by compressed air. From the elevated flask the water siphoned into the basin, emerging finally through the extended outlet tube fixed into the top of the basin. Prior to each experiment, all tubing connected to the basin was freed of air binding by the passage of a small volume of representative water from the overhead flask. The rate of flow throughout the system was sustained within 240–260 ml per minute, with deviations during each individual run limited to 5 ml or less per minute.

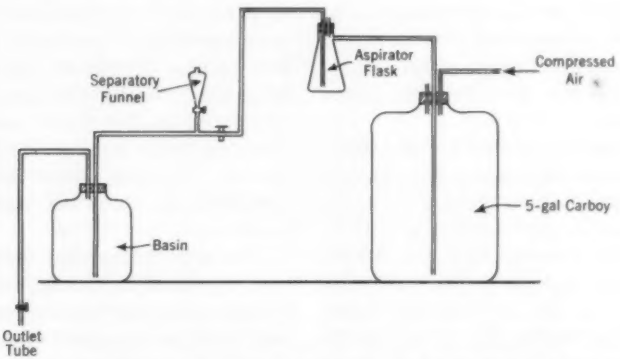


Fig. 1. Laboratory Apparatus for Study of Flow-Through Time

In order to check the validity of flow-through principles, experiments were conducted using common pyrex solution bottles as interchangeable basins. The equipment shown was used for both momentary- and continuous-dose studies.

Effluent samples were collected for an entire minute at 1-, 2-, or 5-min intervals during various runs. For purposes of mathematical calculation, the sampling time was assumed to be equivalent to the 0.5 min during which the sample was collected. For example, the effluent sample collected during the 1-min interval between 12 and 13 min, was assigned the sampling time of 12.5 min in all mathematical computations.

The use of potassium permanganate, alone or in combination with other chemical agents, offered visual indication of the course of water displacement in the basin.

When the influent water was slightly cooler than the water in the basin, and the entrance tube was properly centered, the basin operated under conditions close to ideal. Short circuits could be induced by slanting the entrance tube away from the center, and by admitting slightly warmer water into the basin. All of the experiments were performed with Detroit water, many on raw water which had been coagulated with 10 mg/l of alum.

No attempt was made in these experiments to construct a scale model of an actual plant: only the principle of flow-through time was under examination. The factors governing the displacement of water in the laboratory tank should apply with equal force, however, to the movement of water in a conventional treatment plant.

Ideal-Basin Studies

Continuous-dose method. If a water of uniform chemical composition is continuously treated with a constant dose of an identifying chemical at the inlet to an ideal basin, the effluent will not show the presence of the additive until the treated water arrives at the outlet of the basin. The chemical value of the treated effluent will rise abruptly to the new concentration plateau and subsequently remain stationary at the new level. The customary plot of the data will yield a curve of the general nature of that shown in the upper half of Fig. 2.

In addition to the ordinary graph, the data can be plotted in another fashion, which is more revealing and significant. A valuable picture is obtained when each sampling period is considered as a separate incident and is then presented in its relation to the overall pattern. In the data from the ideal basin represented in Fig. 2, for example, no change in chemical value is evident in the effluent samples collected prior to 25 min, each value being 10 mg/l. On the other hand, the chemical value of the sample collected at exactly 25 min registers 110 mg/l, an increase of 100 mg/l upon the preceding 24.9-min value of 10 mg/l. Since a chemical value of 110 mg/l is found in each succeeding sample, there is no change between the 25-min sample and its successors. Only the 25-min sample is different from its predecessor.

TABLE 1

Hypothetical Data for Continuous-Dose Method in Ideal Basin

1	2	3	4
Sampling Time *min*	Chemical Value* *mg/l*	Incremental Change *mg/l*	Column 1 × Column 3
0	10	0	0
5.0	10	0	0
10.0	10	0	0
15.0	10	0	0
20.0	10	0	0
24.9	10	0	0
25.0	110	100	2,500
25.1	110	0	0
30.0	110	0	0
Thereafter	110	0	0
Total		100	2,500

* Concentration of unspecified reagent in effluent sample.

A plot of these individual changes against the sampling time yields the curve shown in the lower half of Fig. 2. The area under this particular curve can be subjected to mathematical

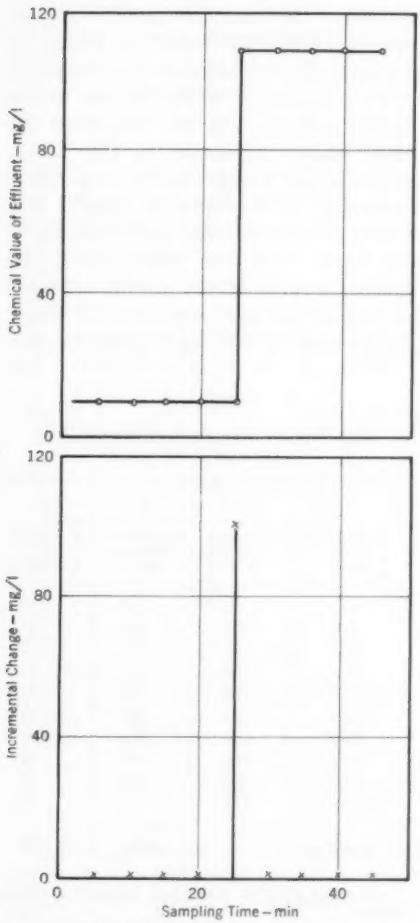


Fig. 2. Hypothetical Displacement Curves for Ideal Basin

Graph in upper half shows concentration of unspecified chemical effluent. Lower graph shows the incremental change in this concentration.

analysis by the method of moments to determine the center of gravity, which corresponds to the flow-through time of the ideal basin.

The steps followed in calculating the center of gravity are implied in Table 1. Column 3 contains the incremental changes between the preceding concentration and the concentration of the sample collected at the time indicated. Column 4 represents the products of columns 1 and 3. Columns 3 and 4 are each totalled, and the total of Column 4 is divided by the total of Column 3 to obtain the flow-through time (in minutes). With the data shown in Table 1, this time, of course, is 25 min. The same procedure may be used to calculate the flow-through periods of actual plant basins.

Momentary-dose method. If a momentary dose of 100 mg/l were added to the ideal basin already considered, a curve identical to that shown in the lower half of Fig. 2 would be obtained when the net chemical values are plotted against sampling time. Calculation of the flow-through time by the center-of-gravity technique provides the same answer with the momentary-dose as with the continuous-dose method, confirming the suspicion expressed by Clifford in 1908.

Simultaneous Experiments

The anticipated similarity in the results was established experimentally by using the same laboratory basin simultaneously with both the momentary-dose and continuous-dose methods. The technique consisted of filling the basin and the carboy with measured volumes of Detroit raw water. The water in the basin received no additional chemical treatment; the contents (18–20 liters) of the 5-gal carboy were charged with one or more chemicals. After thorough mixing, a small volume (10–20 ml) of the dosed water was withdrawn from the carboy for treatment with another chemical selected as the momentary-dose reagent. This solution was then transferred to the sepa-

ratory funnel which was attached to the T tube connecting the basin and the elevated aspirator flask.

The run was started by opening the stopcock of the separatory funnel to admit the momentary-dose reagent into the basin. After the momentary dose had entered the basin and had become properly layered, the pinch clamp on the siphon from the elevated aspirator flask was removed to let the carboy contents into the basin. The entire effluent from the basin was recovered in individual bottles for chemical analysis and measurement of the volume. When the chemical analyses were completed, the effluent was divided into two portions, the first of these representing that portion of the flow from the start to approximately the theoretical detention time of the basin, and the second comprising the flow from the theoretical detention time to the completion of the run.

The measurement of these volumes provided a check on the rate of flow during the two vital intervals of the run. The rate of flow for the entire run was determined by subtracting the volume of water remaining in the apparatus at the conclusion of the run from that present at the commencement of the run.

Figures 3 and 4 show the experimental curves obtained when the basin was operated under an approximation of ideal conditions. Ten milligrams of reagent-grade potassium permanganate was dissolved in 10 ml of the Detroit raw water comprising the continuous dose. The momentary dose was admitted in a uniform layer to the basin, after which displacement was started with cold raw water containing 1.3 mg/l of fluoride (added as sodium fluoride) and 300 mg/l of sodium chloride. The potassium permanganate created no density problem in the basin and allowed observation of the displacement at all stages of the run; furthermore, the potassium permanganate concentration of the effluent could be determined by colorimetric measurement of the characteristic purple color. The sodium fluoride was measured by the Megregian-Maier photometric procedure (*7*). It was necessary, however, to decolorize the potassium permanganate in 100-ml sample with 1–3 drops of 0.1 *N* sodium thiosulfate in the presence of the zirconyl acid reagent before the final addition of the alizarin reagent. The sodium chloride offered a rapid means of following the course of the continuous-dose displacement through conductance measure-

TABLE 2

*Continuous-Dose Data for Approximation of Ideal Basin**

1	2	3	4
Sampling Time *min*	Fluoride Concentration of Effluent *mg/l*	Incremental Change in Fluoride Concentration *mg/l*	Column 1 × Column 3
0–13.5	0.10	0.00	0.0
14.5	0.16	0.06	0.9
15.5	0.18	0.02	0.3
16.5	0.44	0.26	4.3
17.5	0.53	0.09	1.6
18.5	1.01	0.48	8.9
19.5	1.18	0.17	3.3
20.5	1.23	0.05	1.0
21.5	1.26	0.03	0.6
22.5	1.29	0.03	0.7
23.5	1.31	0.02	0.5
24.5	1.34	0.03	0.7
Thereafter	1.34	0.00	0.0
Total		1.24	22.8

* Conditions of experiment: basin capacity, 4,480 ml; rate of flow through basin, 250 ml per minute; theoretical detention time, 17.9 min. Actual flow-through time: 22.8 + 1.24 = 18.4 min.

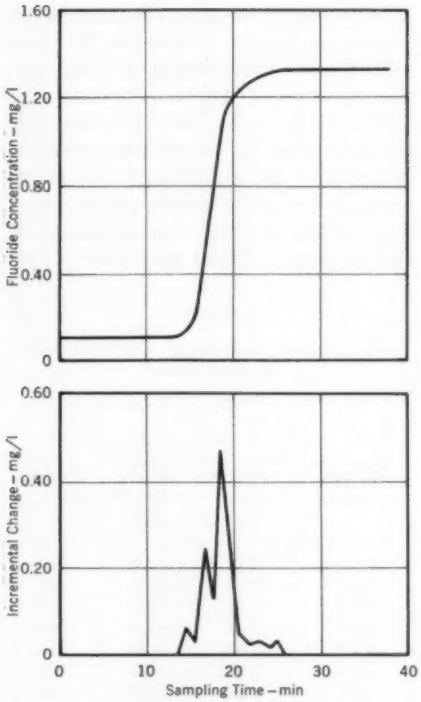


Fig. 3. Continuous-Dose Curves for Approximation of Ideal Basin

As in Fig. 2, the upper graph shows fluoride concentration of effluent, lower graph shows incremental change in this value. The sodium fluoride was measured by Megregian-Maier method.

ments. The three determinations provided a triple check on the entire run.

The mathematical treatment of the fluoride experimental data is presented in Table 2. The following flow-through times were found: by the momentary-dose method, 18.0 min; by the conductance continuous-dose method, 18.1; by the fluoride continuous-dose method, 18.4 min. The theoretical detention time for this particular run was 17.9 min.

The agreement of the flow-through time established by the three determinations was reasonably close. The individual deviations can be explained in part on the basis of the experimental errors inherent in each type of analysis. Inasmuch as the potassium permanganate was read without recourse to additional chemical treatment of the sample, the experimental error in the momentary-dose method was probably smaller than that in the fluoride determination. The fluoride determinations entailed the development of a chemically sensitive lake, providing a potential source of experimental error in each analytical sample. The accuracy of the conductance measurements was limited by the dial markings and the electrical response of the instrument.

As an illustration of the variation that is possible between the momentary- and continuous-dose methods, the following flow-through times should be cited for a run similar to that reported in Fig. 3 and 4: theoretical detention time (calculated from the rate of flow), 18.6 min; momentary-dose method, 17.8 min; continuous-dose method by conductance measurement, 18.8 min; continuous-dose method by fluoride determination, 18.6 min. The slightly low value for the momentary-dose method was attributed to the relatively imperfect initial layering of the potassium permanganate in the basin.

Two plots of the momentary-dose data are shown in Fig. 4. The broken line represents the conventional plot of the data. When the momentary-dose data are considered in terms of incremental change and plotted in the same manner as the continuous-dose data, an additional curve becomes possible. An interesting similarity—and an

equally interesting difference—is revealed by a comparison of this second wave with the continuous-dose curve in Fig. 3. Both curves possess two prominent peaks. The leading peak is the highest in Fig. 4, but in Fig. 3 the reverse is true. The fact that the momentary-dose layer was borne ahead of the continuous dose accounts for the leading peak in Fig. 4. By the same token, dilution with the preceding water repressed the primary peak of the continuous dose.

Limitations

Figures 5 and 6 are graphs of the same experiment when a basin was short-circuited. The usual 10 mg of reagent-grade potassium permanganate in 10 ml of continuous-dose solution constituted the momentary-dose agent. In other experiments, methylene blue dye was used as the momentary-dose reagent and gave comparable results. To facilitate measurement, the continuous-dose solution consisted of 400 mg/l of sodium chloride dissolved in Detroit raw water.

The upper half of Fig. 5 illustrates the nature of the curve when the continuous-dose data are plotted in the conventional manner; the lower half shows the plot of the increment data. Figure 6 pictures the standard momentary-dose curve for the same run. Table 3 presents the data and calculations for the continuous-dose method.

When the data from some of the momentary-dose and the continuous-dose experiments were subjected to mathematical analysis by the method of moments, the flow-through time calculated by the momentary-dose method exceeded the theoretical detention time. This finding demonstrates a serious limitation of the center-of-gravity theorem for computing the flow-through time in liquids. The theorem is applicable to relatively ideal flow patterns. Short circuits can disperse the momentary-dose throughout the basin, thereby prolonging the time required to displace the added chemical from the basin. Consequently, the flow-through time in short-circuited basins, considered alone and without reference to other relevant conditions, can furnish a misleading picture.

The observance of this same phenomenon may have prompted Morrill

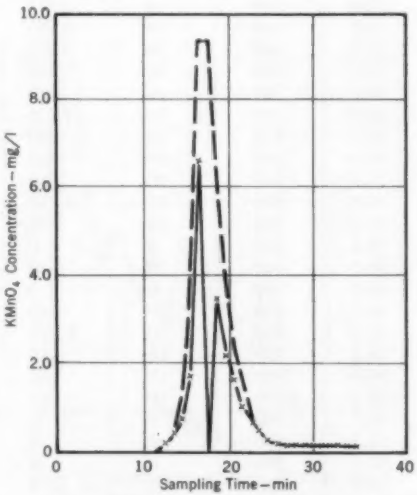


Fig. 4. Momentary-Dose Curves for Approximation of Ideal Basin

The broken line indicates conventional plot of $KMnO_4$ concentration of effluent against sampling time. The solid line shows incremental change. Test conditions were: sampling interval, 1.0 min; basin capacity, 4,480 ml; rate of flow, 250 ml per minute. The theoretical detention time was 17.9 min; the experimental time, calculated in the normal manner, was 18.0 min; and the experimental time, calculated by the method of increments, was 18.1 min.

TABLE 3

*Continuous-Dose Data for Short-circuited Basin**

1	2	3	4
Sampling Time *min*	Specific Conductance of Effluent† *micromhos*	Incremental Change in Conductance *micromhos*	Column 1 × Column 3
0.0	210	0	0
0.5	235	25	13
2.5	355	120	300
4.5	430	75	337
6.5	475	45	293
8.5	520	45	382
10.5	580	60	630
12.5	610	30	375
14.5	660	50	725
16.5	680	20	330
18.5	730	50	925
20.5	760	30	615
22.5	810	50	1,125
24.5	820	10	245
26.5	830	10	265
28.5	840	10	285
30.5	880	40	1,220
32.5	910	30	975
34.5	910	0	0
36.5	930	20	730
38.5	930	0	0
40.5	950	20	810
42.5	980	30	1,275
44.5	970	10	445
46.5	980	10	465
48.5	990	10	485
50.5	990	0	0
52.5	990	0	0
54.5	990	0	0
56.5	990	0	0
58.5	990	0	0
60.5	990	0	0
Total		800	13,250

* Conditions of experiment: basin capacity, 4,640 ml; rate of flow through basin, 255 ml per minute; theoretical detention time, 18.2 min. Actual flow-through time: 13,250 ÷ 800 = 16.6 min.
† Temperature of effluent was 25°C.

to propose a dispersion index for evaluating basin performance (*6*). The Morrill dispersion index has the merit of accenting the chemical recoveries in the effluent. Morrill's dispersion index equals the time required for 90 per cent of the added chemical to pass through the basin divided by the time required for 10 per cent of the added chemical to pass through the basin. The dispersion index equals 1.0 for ideal basins and exceeds that figure for other than ideal basins. A supplementary concept, the reciprocal of the dispersion index, was termed "volumetric efficiency" by Morrill.

Water Treatment Chemicals

The continuous-dose method is adaptable to the investigation of large basins. The ordinary feeding equipment of the plant can be used in the test. Two departures from normal plant routine would characterize a flow-through determination. One would involve the periodic collection of samples of the water entering and leaving the basin. The second departure would involve a substantial increase or decrease—or even complete omission—of the chemical dose to the influent. The magnitude of the chemical increase or decrease must be such as to be readily evident, in time, at the basin terminus.

Several representative water treatment chemicals were studied in some 50 continuous-dose experiments. Chlorine, aluminum sulfate, sodium fluoride, sodium silicofluoride, sodium carbonate, and sodium silicate were found to possess certain advantages for these investigations. No single agent among these six, however, is universally suitable for the determination of the flow-through period of all basins. Each of the chemicals has definite limitations which should be appraised with regard to the peculiar conditions of a specific water supply.

Chlorine, for example, may be applicable in the case of supplies which have a relatively constant or predictable chlorine demand. Moreover, free available chlorine residuals can rapidly be determined by the orthotolidine-arsenite procedure. A photometric modification of this procedure enhances the accuracy of the method. Supplies with a variable chlorine demand would pose a virtually insurmountable problem for a basin test.

The principal disadvantage of alum is the relatively high dosage which must be added to produce acceptable chemical responses. One milligram per liter of alum reduces the total alkalinity approximately 0.5 mg/l and increases the sulfate content in about the same measure. To achieve a total alkalinity and sulfate change in the range of 25–50 mg/l, the required alum dose must approach 100 mg/l. On the other hand, it must be emphasized that an important advantage of alum is that it permits both total alkalinity and sulfate content to be measured and compared for purposes of checking on the reliability of the entire experiment.

From the standpoint of chemical cost, perhaps, the most economical determination of basin flow-through may be accomplished by means of fluoridating agents. A disadvantage of fluoride is its tendency to combine with aluminum to form insoluble aluminum fluoride. Reduction of the alum dose to a bare minimum during the application of fluoride would minimize the removal. Experiments indicate that the fluoride removal is at a rate of about 0.05 mg/l for each 10 mg/l of alum applied. Qualifying the lower chemical costs, however, is the prolonged time required to conduct the fluoride analyses. Phosphates or other interfering substances must be absent from the sample.

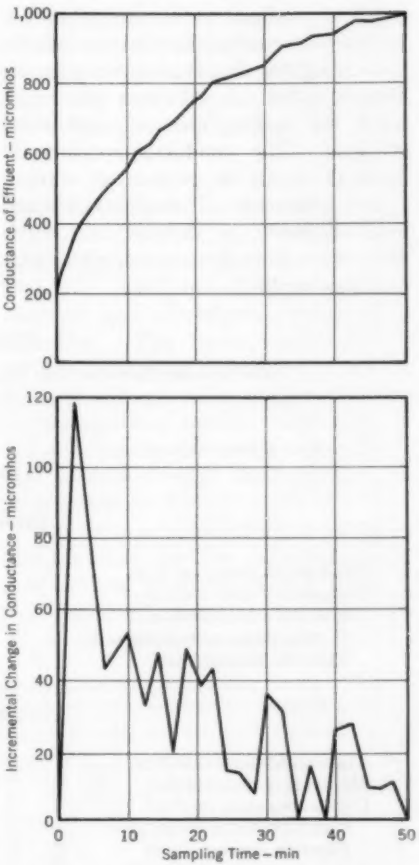


Fig. 5. Continuous-Dose Curves for Short-circuited Basin

Upper half was plotted in the conventional manner, lower half by increment data. The continuous-dose solution, tested simultaneously with momentary-dose reagents, consisted of 400 mg/l of sodium chloride dissolved in raw water.

Sodium carbonate, with an appreciable aqueous solubility, presented fewer problems in handling and feeding than its softening twin, lime, which dissolves with difficulty in water. Doses of 100

mg/l of sodium carbonate permitted the use of a conductance instrument for measuring the dissolved salt content of Detroit water. A pH meter also registered the hydrogen-ion concentration changes. The conductance and pH readings could be performed without sample alteration. Phenolphthalein and total alkalinity, as well as total hardness, were also determined when soda ash was applied.

Sodium silicate, without prior activation, was added successfully in concentrations of 10 mg/l. The multiple manipulations involved in color development and photometric measurement of numerous samples were quite time-consuming.

Although not a treatment chemical in the conventional filtration plant, sodium chloride can be followed by conductance measurements when present in concentrations exceeding 100 mg/l. Capen first used conductance measurements for evaluating basin performance (*4*).

Examination of the data in Table 2 discloses that the sampling interval in the continuous-dose method materially affects the overall results. In general, 1-min sampling intervals enable the isolation of vital chemical changes more exactly than 2- or even 5-min periods. In a plant investigation, however, a practical limit may be imposed on the number of samples which can be collected and subsequently analyzed in a given time. Table 4 shows the relationship between the flow-through time and the sampling period obtained during the comparatively ideal basin experiments illustrated in Fig. 3 and 4. These results reveal that the expected accuracy approximates half of the readings of one sampling interval. The deviation, usually on the positive side, prevails whether the flow-through time is 20, 40, or 60 min.

TABLE 4

Relationship Between Flow-Through Time and Sampling Interval

Type of Determination	Flow-Through Time—*min*		
	1-min Intervals	2-min Intervals	5-min Intervals
Experiment 1			
Theoretical detention time	17.9		
Momentary-dose method	18.1	18.0	18.2
Continuous-dose method			
Conductance measurement	18.2	18.5	20.5
Fluoride measurement	18.4	17.3	20.7
Experiment 2			
Theoretical detention time	18.6		
Momentary-dose method	17.8	17.9	17.4
Continuous-dose method			
Conductance measurement	18.8	19.1	20.7
Fluoride measurement	18.6	18.9	20.5

Conclusions

The immediate objective of these experiments was the study of the flow-through time of fluids in basins. As laboratory units proved satisfactory for the purpose, no attempt was made to construct an actual plant model. In addition to obviating the considerable cost of plant-scale demonstrations, the laboratory experiments permitted the investigation of flow-through time under controlled conditions by the momentary- and continuous-dose methods at the same time and during the same run.

There is every reason to suppose that the laboratory findings are applicable on a plant basis. The comparatively ideal flow pattern in the large tunnel delivering raw water by gravity to the Springwells Station of the Detroit Department of Water Supply was immediately evident upon the installation of a residual chlorine recorder at the Springwells end of the tunnel. Adjustments in the continuous-chlorine dosage at a chlorination station near the tunnel entrance, more than 5 miles distant, were eventually registered as precipitate rises or falls on the graph of the residual-chlorine recorder. The rises and falls resembled those typical of ideal flow-through curves.

The laboratory experiments indicate that the continuous-dose method yields the same results as the accepted momentary-dose method. Both methods can be used simultaneously in the study of basin performance and efficiency, thereby allowing one method to serve as a check on the other. The advantages of such a course are underscored by the difficulties attending the proper application of the momentary dose. The parallel use of the two methods will quickly reveal a discrepancy in the results and indicate characteristics of the flow which a single method might miss. Agreement in the results, on the other hand, would confirm the reliability of the data.

The merit of the continuous-dose method resides in the fact that normal treatment chemicals can be applied for the determination of flow-through time; also, the maintenance of a constant chemical feed reproduces routine plant operation. The special problems involved in charging sufficient momentary doses to a large basin suggest that the continuous-dose method may offer a suitable substitute for the determination of flow-through characteristics in such instances.

The most economical study of flow-through time by the continuous-dose method can be accomplished when a new treatment (such as fluoridation), or a change in coagulants or the

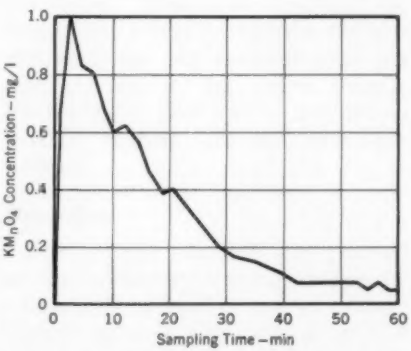


Fig. 6. Momentary-Dose Curve for Short-circuited Basin

Experimental conditions included a sampling interval of 2.0 min, a basin capacity of 4,640 ml per minute, and a rate of flow through the basin of 255 ml per minute. Theoretical detention time was 18.2 min, experimental flow-through time 16.1 min.

method of chlorination, is being introduced into plant operation. The discontinuance of a chemical treatment offers a similar opportunity for a basin test. The possibilities inherent in the start of a new treatment are illustrated by the case of the water utility serving Washington, D.C. This department availed itself of the opportunity to study the flow patterns in the distribution system when fluoridation was instituted at the treatment plant (*8*).

Acknowledgment

The author gratefully acknowledges the invaluable suggestions and assistance in the construction and operation of the laboratory basins and in the performance of the required chemical analyses provided by James Hornung and Marion McCall, Sanitary Chemists, Detroit Department of Water Supply.

References

1. Annual Report, 1904. Massachusetts State Board of Health, Boston, Mass.
2. CLIFFORD, W. The Time of Passage of Liquid Through Percolating Beds. *J. Soc. Chem. Ind.* (Br.), **26**:739 (1907).
3. CLIFFORD, W. The Measurement of the Velocity of Water Through Filter Media. *J. Soc. Chem. Ind.* (Br.), **27**:658 (1908).
4. CAPEN, C. H., JR. Study of Sewage Settling-Tank Design. *Eng. News-Record,* **99**:833 (1927).
5. *Water Quality and Treatment.* Am. Wtr. Wks. Assn., New York (2nd ed., 1950). p. 179.
6. MORRILL, A. B. Sedimentation Basin Research and Design. *Jour. AWWA,* **24**:1442 (Sep. 1932).
7. MEGREGIAN, S. & MAIER, F. J. Modified Zirconium-Alizarin Reagent for Determination of Fluoride in Water. *Jour. AWWA,* **44**:239 (Mar. 1952).
8. LEVIN, G. V. & JACKSON, N. E. Use of Fluoride as a Tracer in Distribution System Studies. *Jour. AWWA,* **45**:264 (Mar. 1953).

Continuous Production of Activated Silica With Low-CO_2 Gases

R. V. Andrews and Joe W. Burdett

A contribution to the Journal by R. V. Andrews, Dean of Eng., Lamar State College of Technology, Beaumont, Tex., and Joe W. Burdett, Shell Oil Co., Research Labs., Houston, Tex.

IN a previous study (*1*), the continuous production of activated silica with pure carbon dioxide gas has been discussed. Because flue gases from boiler plants and exhaust gases from diesel engines are common free sources of carbon dioxide, experiments were conducted using gases of this type for the continuous preparation of activated silica, and a set of process variables was established which could be used for the commercial preparation of activated silica.

Because commercial use was the primary goal, the essential equipment was kept as simple and inexpensive as possible. Additional items of equipment, not necessary for the actual production of activated silica, were then added to determine accurate data on the effect of process variables. A synthetic flue gas consisting of a mixture of air and carbon dioxide was used in all experiments, the air serving to dilute the carbon dioxide to the desired volume percentage.

Equipment

The process equipment is shown in Fig. 1. Its essentials are a proportioning pump and orifice mixer for diluting the sodium silicate to the desired strength, a compressor to supply gas under pressure, another orifice mixer to react sodium silicate solution with the gas containing carbon dioxide, and a phase separator to separate the liquid activated-silica solution from unreacted gases. This phase separator is not absolutely necessary, but its use gives an effluent stream of liquid activated silica rather than a froth of gas and liquid.

For operation of the equipment, air and carbon dioxide gas, each at 60 psig, were metered through separate rotameters and added together in a pipe T just ahead of the total gas rate control valve. This valve regulated the flow of the mixed gases from the system, and, for any constant total gas rate, changes in the carbon dioxide control valve varied only the carbon dioxide content of the mixed-gas stream.

Operation

The sodium silicate * was pumped to the secondary mixing orifice by means of a ball-valve type of proportioning pump. The setting of the pump controlled the flow rate of the sodium silicate. Water from the city mains or from a storage tank was passed through a rotameter and then mixed with the sodium silicate in the secondary mixing orifice. The dilute sodium silicate solution and the gas

* N brand sodium silicate, a product of Philadelphia Quartz Co., Philadelphia, Pa., was used.

stream were then mixed in the main orifice. Mass transfer of the carbon dioxide from the gas to the liquid took place from the time the two phases were mixed at the orifice until they were separated in the phase separator. This time of reaction was varied by changing the length of pipe between the main mixing orifice and the phase separator. Provisions were made for water flushing of all piping and equipment which came in contact with the silicate solution to prevent possible gelling of residual sodium silicate during shutdown periods.

Tests

Samples taken during operation of the equipment were analyzed for percentage neutralization and equivalent silica content by standard means, except that a pH meter was used to determine titration end points instead of the usual indicators described by C. R. Henry (*2*) and *Standard Methods* (*3*). In addition, jar tests, such as those used by Henry, were employed to determine the activity of the sol produced. Equipment and handling limitations set a minimum aging time of 30 sec before testing the samples for

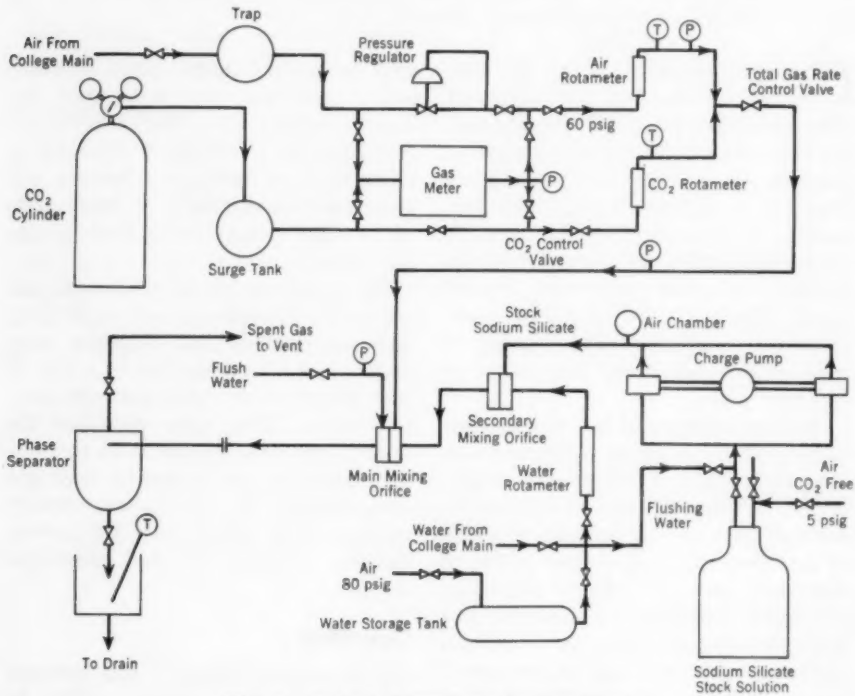


Fig. 1. Activated Silica Production Plant

Although the phase separator is not absolutely necessary, its use insures an effluent stream of liquid activated silica rather than a froth of gas and liquid.

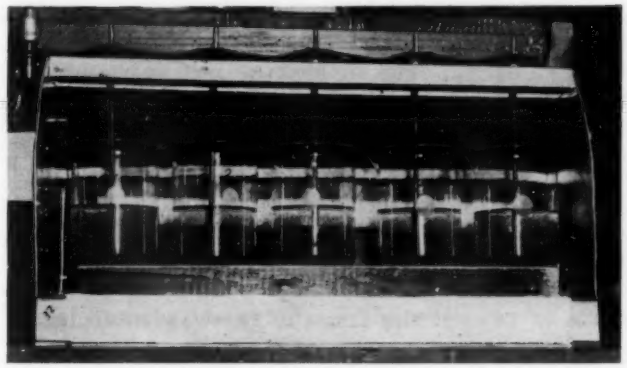


Fig. 2. Jar Test Results

The jar at far left involves alum only. Other jars have alum and activated silica.

activity. A typical jar test result is shown in Fig. 2.

In these experiments, an aging time of 30 sec, a pipe Reynolds number (**R**) of 5,000, and an equivalent solution silica content of 3 per cent were held as constant as possible. The variables investigated were gas rate, orifice diameter, percentage of carbon dioxide content of the gas, gas pressure at the mixing orifice, and pipe length between the main orifice and the phase separator.

The total gas pressure, P_o, at the main mixing orifice had only a small effect on the percentage neutralization, as shown in Fig. 3. The percentage neutralization was found to in-

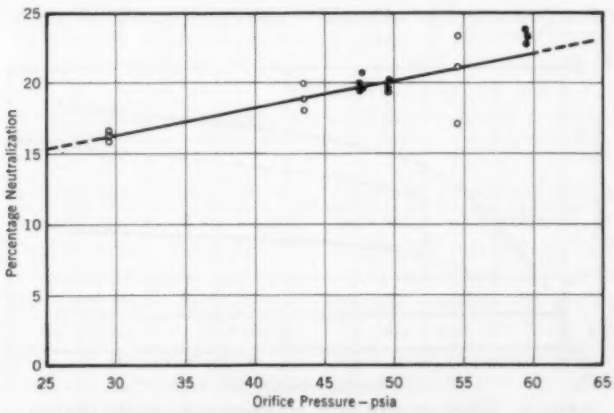


Fig. 3. Effect of Orifice Pressure on Percentage Neutralization

Data for $\frac{7}{16}$-in. orifice are indicated by ○; for $\frac{1}{2}$-in. orifice, by ●.

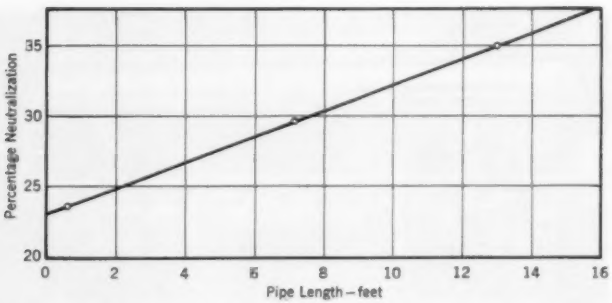


Fig. 4. Effect of Pipe Length on Percentage Neutralization

Approximately half of the neutralization reaction occurred in the orifice mixer, showing that the rate of reaction was greatest in the zone where residence time was extremely small.

crease linearly with absolute orifice pressure and was essentially independent of orifice diameter except at very low gas flow rates. Apparently, some minimum amount of turbulence was required for the reaction to proceed at a reasonable rate. If the pipe flow rate was not sufficient to produce this amount of turbulence it could be obtained by inserting orifice restrictions in the system. Increasing turbulence beyond this minimum value did not aid in increasing percentage neutralization; it only increased pumping charges.

The pipe length between the main orifice and the phase separator was varied from 8 in. to 13 ft. An increase in pipe length gave a linear increase in the percentage neutralization, as shown in Fig. 4. Approximately half of the neutralization reaction occurred in the orifice mixer, however, showing that the rate of reaction was greatest in this zone where residence time was extremely small. From this point on

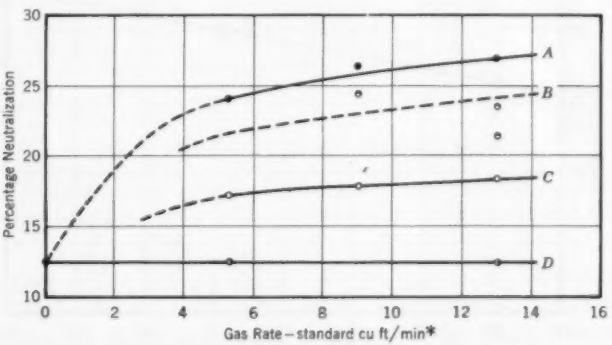


Fig. 5. Effect of Gas Rate on Percentage Neutralization

Carbon dioxide contents for the four curves are as follows: Curve A*—15 per cent; Curve* B*—10 per cent; Curve* C*—4 per cent; and Curve* D*—0 per cent.*

the reaction continued, but at a relatively slow rate.

The effect of gas flow rate on the percentage neutralization is shown in Fig. 5. Beyond a point at which the gas rate, in comparison with the liquid rate, was sufficient to supply a required amount of carbon dioxide for neutralization, only a small increase in percentage neutralization was obtained with increasing gas flow rates. This increase was greater for gases with

The effect of the carbon dioxide content of the gas is shown in Fig. 6. A linear increase in percentage neutralization was obtained with increases in the volume percentage of carbon dioxide in the gas, and, as previously discussed, the percentage neutralization was affected only slightly by large changes in the total gas flow rate.

Satisfactory operating conditions which produced an active silica sol ready for use within 30 sec were: 6.3

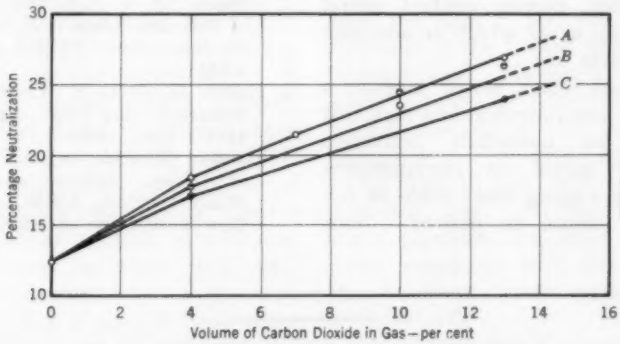


Fig. 6. Effect of Carbon Dioxide Content on Percentage Neutralization

The gas rates for the three curves are as follows: Curve A—*13 standard cubic feet per minute; Curve* B—*9 standard cubic feet per minute; and Curve* C—*5.3 standard cubic feet per minute.*

* Standard cubic feet per minute is a unit of measure based on the volume of gas at 60°F.

higher carbon dioxide content but was not a pronounced effect. Two factors apparently exist which work against each other. An increasing gas rate increased the turbulence and contact area, which increased the percentage neutralization. At the same time, the increased gas rate decreased the residence time and so decreased the percentage neutralization. The net effect was a slight increase in the actual percentage neutralization obtained.

standard cubic feet per minute of 10 per cent CO_2-content gas; a liquid Reynold's number of 5,300; a 2.9 per cent equivalent SiO_2-content sodium silicate solution; an orifice pressure of 60 psia; and 13 ft of ⅛-in. Iron-Pipe Size (I.P.S.) exit pipe between the main orifice and the phase separator.

Although 30 sec was set as the minimum aging time for use on a continuous basis, aging times of several minutes and several hours were used

in activity tests. These tests did not indicate any noticeable loss or increase of activity with a change in the aging time. Also, no effect on activity was obtained for small variations in silica content.

Conclusion

While the above conditions are known to be entirely satisfactory, the data presented here and work which is now in progress indicate that a smaller orifice pressure and a gas with lower carbon dioxide content would also produce a sol which is adequate for immediate use.

Conditions which would produce a percentage neutralization less than that required for immediate activation would be useful in circumstances where longer aging times could be tolerated or would be desired. Such conditions would be useful in replacing or supplementing existing batch systems where an inexpensive supply of flue gas is available.

Acknowledgment

The work represented by this article was financed by and under the auspices of the Texas Engineering Station, College Station, Tex.

References

1. Andrews, R. V. Continuous Production of Activated Silica With Carbon Dioxide Gas. *Jour. AWWA*, **46**:82 (Jan. 1954).
2. Henry, Clarence R. Characteristics of Activated Silica Sols. *Jour. AWWA*, **41**:551 (Jun. 1949).
3. *Standard Methods for the Examination of Water, Sewage, and Industrial Waste.* APHA, AWWA, & FSIWA, New York (10th ed., 1955).

Correction

The paper "Snail and Clam Infestations of Drinking-Water Supplies" by William Marcus Ingram (March 1956 Journal, Vol. 48, pp. 258–268) contained an editorial error. The title for Fig. 1, p. 260, indicated that all the snails shown were common to United States water supplies. *Melania tuberculata* Muller snails shown in Fig. 10, however, were reported in the Singapore infestation and do not occur in the United States. The title for Fig. 1 should have read "Snail Genera Associated with Water Supplies."

Suggested Nontechnical Manual on Corrosion for Water Works Operators

Lee B. Hertzberg

A revision of a paper presented on Oct. 28, 1954, at the California Section Meeting, Long Beach, Calif., by Lee B. Hertzberg, Sr. Elec. Engr., East Bay Municipal Utility Dist., Oakland, Calif.

THE majority of manuals, books, and papers covering the technical aspects of corrosion theory and control have been written by and for corrosion engineers. Consequently, they make difficult reading for personnel untrained in corrosion terminology. A few manuals, primarily in the natural-gas and petroleum industries, have been written for operating personnel, and an outstanding example is *A Manual on Underground Corrosion* (*1*). A similar manual on corrosion control, written for water works personnel, was needed.

The East Bay Municipal Utility District, Oakland, Calif., recently issued a Manual on Corrosion Control (*2*) to its operating and engineering employees. The manual was designed to give employees a basic understanding of corrosion theory and control. This article is an outgrowth of that manual.

Corrosion Costs

Water works utilities have large investments in metallic structures, most of which are underground. Corrosion in such structures is a never-ending problem, causing economic loss by a process which resembles a chain reaction. A corroded pipeline may leak or break, thus wasting valuable water, damaging property or people, and possibly causing loss to the customer because of interruptions to his business. As a result, the utility may be faced with law suits and other effects of adverse public relations, plus the repair or replacement cost of the pipeline.

H. H. Uhlig (*3*) estimated that in 1950 the total annual loss caused by corrosion in the United States was 5.5 billion dollars. The repair and replacement of over a 1,000,000 miles of buried pipelines in this country was estimated to cost $600 per mile, or more than 10 per cent of the total corrosion loss. In the same year, water pipelines amounted to 263,000 miles, which, at $600 per mile, cost the American water works industry $158,000,000.

The Correlating Committee on Cathodic Protection estimated that, in 1951, corrosion directly or indirectly caused repairs and replacements of underground structures costing one billion dollars (*4*). In July 1954, L. V. McIntire of the Southwestern Louisiana Institute, Lafayette, La., estimated that 30–40 per cent of the annual steel output for the United States is used to replace metal lost by corrosion (*5*).

The above figures are estimates; actual cost data are extremely difficult to obtain because, as shown above, corrosion can result in so many contingent losses. The East Bay district has compiled maintenance cost records on its 2,300 miles of distribution mains for the 5-year period ending in July 1954. Figure 1 shows these costs calculated

on a dollars per year per mile of main basis. The 5-year average cost of all repairs and replacements chargeable to mains was $86.64 per year per mile. Because this figure included maintenance costs of valve boxes, manholes, main gate valves, main pressure regulators, and all types of mains including asbestos cement, the entire cost cannot be charged to corrosion. Repair and replacement of metallic mains, excluding appurtenances, was $52.43 per year per mile. This cost is largely chargeable to corrosion.

Well over half of the district's distribution mains are buried in highly corrosive soil. The low maintenance cost per mile results primarily from an aggressive corrosion control program which was started over 30 years ago.

Corrosion Theory

Relatively few people understand the basic concepts or practical methods of reducing corrosion damage. Corrosion is an electro-chemical attack on refined metals, by which they revert to their original natural form of ores or chemical compounds. It is electro-chemical because the chemical action is either caused by or causes the flow of electric current. The four types of corrosion are galvanic, electrolytic, stress, and biochemical.

Galvanic Corrosion

Where rapid corrosion occurs it is usually a result of galvanic action between dissimilar metals. This action is identical with that found in an ordinary flashlight cell. Such a dry cell consists of the anode (zinc case), the cathode (carbon rod), and electrolyte (moist filler between case and rod). The electrical connection or external circuit between anode and cathode con-

TABLE 1

Galvanic Series of Metals and Alloys†*

↑ Anodic or Corroded End	Magnesium and magnesium alloys
	Zinc
	Aluminum 2S
	Cadmium Aluminum 17 ST
	Steel or iron
	Cast iron
	Chromium-iron (active)
	Ni-Resist
	18-8 Stainless steel (active) 18-8-3 Stainless steel (active)
	Hastelloy "C"
	Lead-tin solders Lead Tin
	Nickel (active) Inconel (active)
	Hastelloy "A" Hastelloy "B"
Cathodic or Protected End ↓	Brass Copper Bronzes Copper-nickel alloy Monel
	Silver solder
	Nickel (passive) Inconel (passive)
	Chromium-iron (passive) 18-8 Stainless steel (passive) 18-8-3 Stainless steel (passive)
	Silver
	Graphite Gold Platinum

* A "passive" metal has a surface film of absorbed oxygen or hydrogen. A metal may be initially "active" and become "passive" to the other metal when the protective film is formed.

† Composition of items is as follows: Aluminum 17ST—95% Al, 4% Cu, 0.5% Mn, 0.5% Mg; Ni-Resist, International Nickel Co., New York, N.Y.—austenitic nickel and cast iron; 18-8 stainless steel—18% Cr, 8% Ni; 18-8-3 stainless steel—18% Cr, 8% Ni, 3% Mo; Hastelloy "C", Union Carbide and Carbon Co., Niagara Falls, N.Y.—59% Ni, 17% Mo, 14% Cr, 5% Fe, 5% W; Inconel, International Nickel Co., New York, N.Y.—59–80% Ni, 10–20% Cr, 0–23% Fe; Hastelloy "A"—60% Ni, 20% Mo, 20% Fe; Hastelloy "B"—65% Ni, 30% Mo, 5% Fe; and Monel—63–67% Ni, 29–30% Cu, 1–2% Fe, 0.4–1.1% Mn.

sists of the metallic path from one dry-cell terminal, through the switch and lamp, to the other dry-cell terminal. When the switch is closed the zinc-case anode corrodes, being sacrificed to provide the electric current through a chemical reaction.

When metallic structures are underground, a galvanic cell exists because the most soil acts as the electrolyte, the external circuit being the metallic contact between two dissimilar metals which act as anode and cathode according to their relative positions in the "galvanic series." A metal can be anodic at one time, cathodic at another, depending on the dissimilar metal acting with it.

The galvanic series in Table 1 shows the voltage relationship between commonly used metals. If any two metals in this series are placed in an electrolyte and are externally connected, the metal listed nearest the top of the series will corrode—that is, it will be anodic. The other metal will not corrode. Metals grouped together in the series are relatively safe to use in contact with each other, even when installed in an environment where a galvanic action could occur.

It is sometimes necessary to build a pipeline or metallic structure using dissimilar metals in contact, such as cast iron with dipped and wrapped steel, or galvanized iron with brass. To reduce corrosion effects, the cathodic area should be kept as small as possible and the anodic area should be as large as possible and heavy enough to withstand the loss of metal by corrosion.

Galvanic action occurring between identical metals in different electrolytes is similar to galvanic action occurring between dissimilar metals in a common electrolyte. In submerged or buried water works structures, such differences in electrolytes can result from a difference in ion concentrations, in dissolved-oxygen concentrations, in soil types, or in amounts of dissolved chemicals in the soil.

Ions are charged atoms or molecules in a solution. When moisture is in contact with a metallic surface some of the metal will go into solution as metal ions. The lower the ion concentration, the more chance there will be for the metal to ionize and dissolve. If there are two areas along a common metallic surface with different ion concentrations, a galvanic voltage will develop between them. These areas are called "concentration cells." The greatest corrosion will occur at the cell which has the lowest ion concentration and the current will flow away from that point through the electrolyte, carrying metal with it.

Oxygen concentration cells can create galvanic voltages in a manner similar to metal ion concentration cells. A metallic surface in contact with a solution where the amount of dissolved oxygen at one point is considerably greater than at another point will corrode at the point of lower concentration. In most soils, for example, the soil near the upper portion of a buried pipeline will have a higher oxygen concentration than the soil near the bottom of the pipe. A galvanic voltage is created between the top and bottom of the pipeline, and the bottom will corrode.

The amount of galvanic corrosion which a buried metallic structure undergoes is largely determined by the soil type in which the structure is buried. Soils are generally classified as acid, neutral, or alkaline. Corrosion is usually more rapid in acid soils.

According to their resistivity, soils are classified as good, bad, or very

bad. Resistivity is measured in ohms per cubic centimeter, abbreviated as ohm-cm[3] or ohm-cm. A soil with low resistivity (high conductivity) will usually have a high corrosion rate. Representative values are 1,000 ohm-cm or less for very bad soils, 2,000 ohm-cm or higher for good soils.

Within the district's "local-system" area, 2,000 ohm-cm has been arbitrarily chosen as a borderline between the good and bad soils. The bad soils are mainly the blue mud or muck, adobe, clay, and certain clay and silt loams. All good soils contain low-resistivity "islands" consisting of small deposits of poor soils, rocks, or foreign materials.

Figure 2 shows the effect of soil resistivity on the number of pipeline repairs required because of corrosion during the life of the pipeline (*6*). Figure 3 gives similar information in a different way, illustrating the relation between maximum depth of corrosion pits and the time of exposure of the pipe to various soil types (*7*).

A pipeline passing from a high-resistance (good) soil to a low-resistance (bad) soil will corrode in the low-resistance soil because of the difference in pipe-to-soil potentials of the two soil areas. The current flows from the pipe, through the bad soil to the good soil, then back to the pipe.

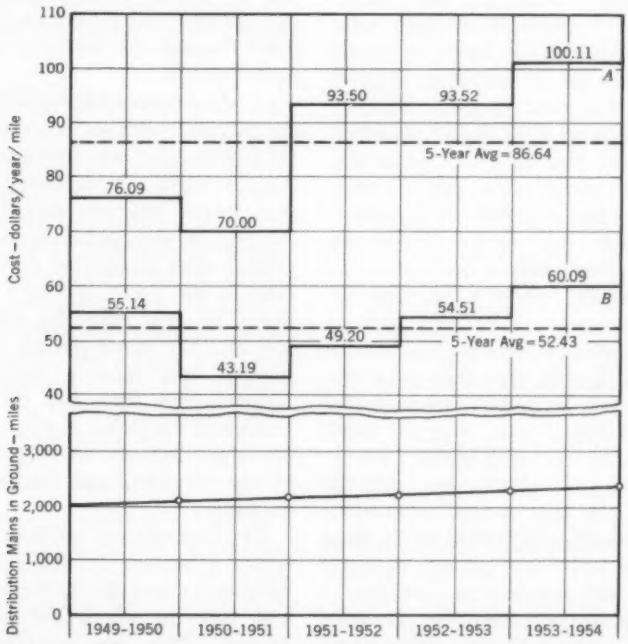


Fig. 1. Costs for Repair and Replacement of Main Pipeline, East Bay Municipal Utility District—1949–54

Curve A *represents data for all costs chargeable to mains, including repairs to all mains, valve boxes, manholes, main gate valves, and main pressure regulators; Curve* B, *repairs chargeable only to metallic mains.*

Electrolytic Corrosion

Electrolytic corrosion, or electrolysis, is man-made. Its usual source is stray currents from electric railways, most of which have a d-c generator supplying power to the trains through an overhead trolley wire. The current is supposed to return to the generator through the rails. Actually, because of high resistance in poorly connected rail joints, the current leaves the rails in favor of the lower-resistance paths offered by underground pipelines, cables, or structures. Normally, no harm is done where the current enters the pipes or cables, but corrosion occurs where the current leaves the pipes or cables to return to the d-c generator, because, from this point, the current carries particles of metal with it.

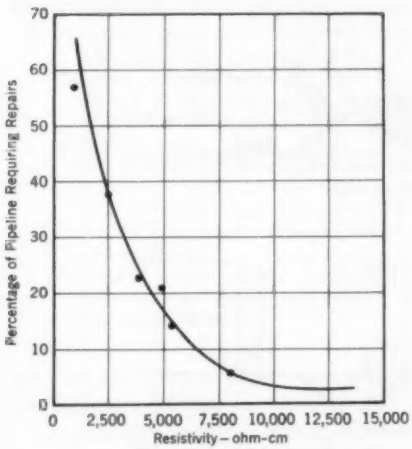


Fig. 2. Pipeline Repairs Related to Soil Resistivity

The percentage of repairs shown are for the average life of pipe.

Other Types of Corrosion

Stress corrosion of metals is usually caused by local stresses in the material. These may be residual stresses from the fabrication process or operational stresses set up by loading. Season-cracking of brass is one example. Another is that of filed-off stamped numbers on metal which has been treated with an etching reagent. The numbers reappear because the stamped portions corrode faster than the surrounding material.

Metals under stress are not always more corrosion-susceptible. Uniformly distributed stresses normally do not impair corrosion resistance.

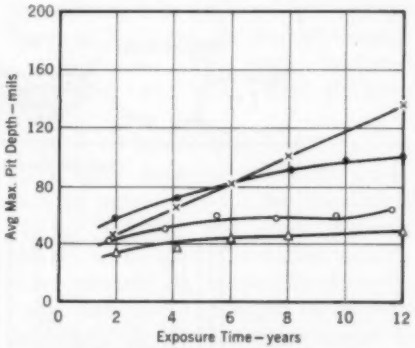


Fig. 3. Pit Depth Related to Duration of Pipeline Exposure

Data shown are for the following soils and resistivities: x—muck and blue mud, 200–500 ohm-cm; ●—clays, 300–1,200 ohm-cm, and clay loam, 1,100–2,000 ohm-cm; ○—loam and clay loam, 1,800–4,000 ohm-cm; and △—sand and sandy loam, 3,000–10,000 ohm-cm.

Biochemical corrosion results from chemicals produced by soil bacteria. At present, sulphate-reducing bacteria appear to be the major cause of extensive corrosion of this type in soil and water (*8–10*). The metabolic products of these bacteria act to combine any available sulphur with water, forming sulphurous and sulphuric acid, an excellent electrolyte which accelerates any possible galvanic action. There

seems to be no particular relation between soil resistivity and this bacteriological action, and, accordingly, joint material containing sulphur should not be used unless it is actually tested in soil samples taken from the pipeline excavation (*11*). Because such tests were very expensive, the district discontinued use of any sulphur-bearing joint material more than 10 years ago.

Corrosion Control

Corrosion can be reduced or prevented by insulation, bonding, cathodic protection, and proper structure design. Insulation is used to stop galvanic action by interrupting the external metallic circuit so that galvanic current cannot flow. Bonding is used to reduce electrolysis by providing a continuous low-resistance metallic path so that man-made direct curents can return to their source without passing to ground from any metallic structure.

Cathodic protection, used in either case, is the application of a d-c current in a direction opposite to that normally flowing in the electro-chemical circuit. The net galvanic current is thus reduced to a harmless amount.

Corrosion control by proper structure design means selection and positioning of materials to avoid galvanic interaction. This is usually the cheapest method of corrosion control.

Insulation

Insulation is the first general method of corrosion protection. It includes the use of insulating joints in pipelines and of localized protection by paints and other coatings.

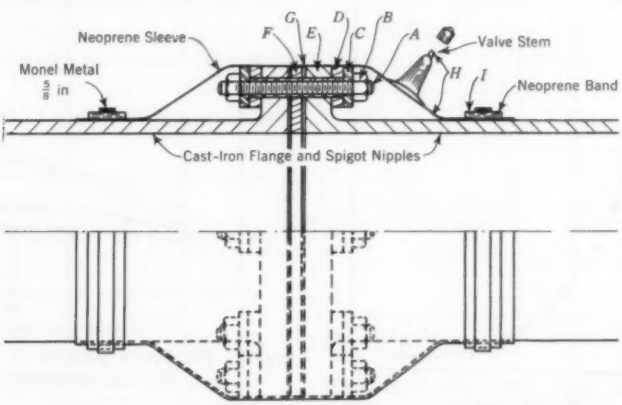


Fig. 4. Details of Cast-Iron Insulating Joint, ASA Class 125

Flange drilling is in accordance with ASA Class 125. For pipe sizes of 4–8 in., flange and spigot nipples of 18-in. length should be used. For pipe sizes of 10–16 in., 24-in. lengths should be used. The monel metal shown is banding.

Pipe coated with cement mortar is cathodic to bare cast iron or steel, causing the bare pipe to corrode if it is directly connected to the coated pipe. Dipped and wrapped pipe, when directly connected to the pipe coated with cement mortar, acts like bare pipe as soon as the slightest defect develops in the dipped and wrapped coating. In addition, because the area of any defect is very small compared to the entire

TABLE 2

Description of Materials

Item	Description
A	Stud bolt, heat-treated high-tensile alloy steel, 105,000-psi yield point, ASA N.C., thread entire length
B	Hexagonal nut, medium carbon, oil-quenched, semi-finished Am. Std. Heavy Series, size and thread to fit stud bolt
C	Steel washer, $\frac{3}{8}$ in. thick, round, faces to be flat and parallel
D	Bakelite washer, $\frac{1}{2}$ in. thick, square
E	Bakelite sleeve, length is $\frac{1}{8}$ in. less than distance between steel washers (Item 3)
F	Bakelite gasket, $\frac{1}{8}$ in. thick, full face, ASA Class 125 flange drilling
G	Asbestos-composition gasket, full face, without graphite, bolt holes to match ASA Class 125 flange drilling
H	Molded-neoprene rubber sleeve, $\frac{1}{16}$-in. min. thickness, 40-durometer neoprene, neoprene rubber–covered tire valve stem with plastic cap, Schraeder Valve No. 15 R or approved equal, vulcanized to sleeve
I	Molded-neoprene rubber band, $\frac{3}{16}$-in. min. thickness, $1\frac{1}{2}$-in. min. width, 40 durometer neoprene

area of the coated pipe, corrosion at the defect is greatly increased.

To stop this galvanic action, insulating joints must be used where a steel pipe coated with cement mortar is connected to a cast-iron, a bare steel, or a dipped and wrapped pipe. These joints are usually special cast-iron or steel insulating flanges, asbestos-cement nipples, or insulating sleeve couplings. Cast-iron insulating joint details, having flange drilling conforming with ASA Class 125, are shown in Fig. 4, and steel insulating joint details, with flange drilling conforming with ASA Class 150, are shown in Fig. 5.* The item numbers shown in Fig. 4 and Fig. 5 refer to Table 2.

In Fig. 6, because the outside diameter (OD) and thickness (t) of the steel skirt must match the corresponding pipe dimensions, it is always necessary to verify the actual OD and t of the steel pipe cylinder for which the joint is being fabricated. The values of t shown are nominal.

When the insulated joint is made at the flange of a valve, the length of the stud bolts (Item *A*) and bakelite sleeves (Item *E*) must be increased by the difference in thickness between the flange on the valve and the ASA standard thickness. The flange thickness on valves will vary with different manufacturers.

On some valves, there will be insufficient space between the valve flange and the valve body for the installation of the bakelite and steel washers. When such space limitation occurs, these washers are omitted on the valve flange side, and the length of the stud bolts and bakelite sleeves decreased by an amount equal to the total thickness of the omitted washers.

On installations in 16-in. pipe or larger, the Portland cement–mortar lining should be replaced at the welded joint connecting the nipple to the steel pipe. The rubber gasket is of the solid, $\frac{1}{4}$-in. thick, round rubber ring type. The backs of the flanges should be smooth and parallel to the corresponding front face. If the flange fillet interferes with the bakelite washer, sufficient material should be removed from the edge of the washer to just clear the fillet, avoiding excessive heating of the washer. A silicone grease is applied to the bolt threads and to the inside of the bolt holes at the gaskets before installing the bolts and sleeves, but no metallic or other non-insulating-type paint should be used

* For both Fig. 4 and 5, the following specifications apply: "bakelite parts are to be made of a laminated, phenolic-resinoid, paper-base bakelite, grade 500, double-*X*, having a compressive strength of 40,000 psi, tensile strength of 13,500 psi across the grain, and maximum moisture absorption (based on $\frac{1}{8}$-in. thickness) of 1.12 per cent in 24 hr. Asbestos gaskets are to be Garlock Style No. 7021 or Johns-Manville No. 715 or approved equal."

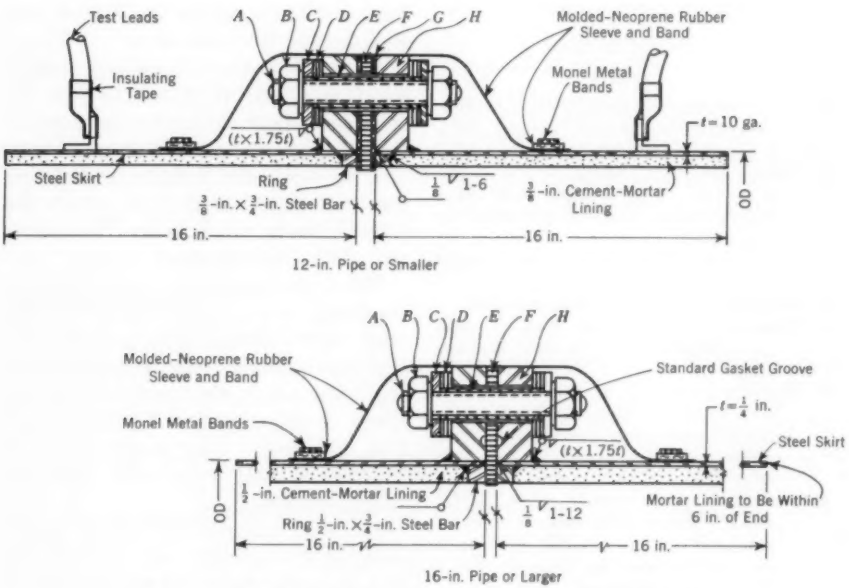


Fig. 5. Details of Steel Insulating Joint, ASA Class 150

Flange drilling is in accordance with ASA Class 150.

on any part of the joint, nor should the inside of the joint insulation be bridged with cement-mortar lining. After the joint is assembled, the insulation is tested electrically to make certain that the two halves of the joint are actually electrically insulated from each other. If the joint tests satisfactorily, one coat of a rubber adhesive sealer * is applied and allowed to dry. The neoprene sleeve is then slipped over the entire joint and banded at each end, using monel straps, in the way that boxes are banded. Backfill should be free of rocks and clods, and particular care should be observed to avoid all abrasion or puncturing of the neoprene covering.

Figures 6–9 show installation details of the various types of insulating joints.

In Fig. 6 the cast-iron insulating joint described in Fig. 4 is shown installed in the field. Where a field mortar coating is specified, cement mortar is applied to a minimum thickness of $\frac{3}{4}$ in. over a 2-in. × 4-in. No. 12 gauge wire-mesh reinforcement. For pipe sizes of 8 in. or less and for maximum pressures of 100 psi (including surges), asbestos-cement insulating joints shown on Fig. 8 are used.

The top two illustrations of Fig. 7 show the field installation of the steel insulating joints described in Fig. 5. The bottom illustration shows a combination steel and cast-iron insulating joint, which is used only when special conditions prevent the use of a standard cast-iron or steel insulating joint.

Practice is to test electrically each insulating joint before it leaves the factory, when it arrives at the job site

* The sealer referred to throughout this paper is EC-244 Adhesive, a product of The Minnesota Mining and Manufacturing Co., St. Paul, Minn.

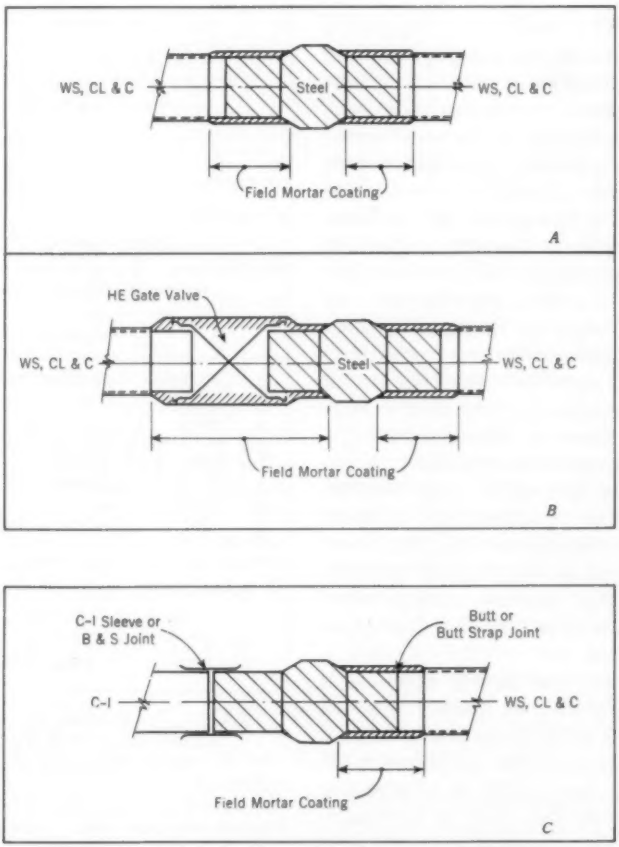


Fig. 6. Installation of Cast-Iron Insulating Joint

B & S stands for bell and spigot; CI for cast iron; WS for welded steel; CL for cement-mortar lined; C for cement-mortar coated. Cement mortar–coated cast-iron pipe is treated as WS, CL & C pipe. Coal tar enamel– or asphalt-coated pipe is considered the same as bare pipe.

and after one end has been connected to the pipe. The neoprene sleeve has a valve which is similar to a tire valve and the sleeve is tested just before backfilling by inflating to 4-lb pressure and checking for air leakage.

Asbestos-cement pipe insulating joints are shown in Fig. 8. Because wet asbestos-cement is only about one-third as effective an insulator as the steel- or cast ion–bakelite combinations, this type of insulating joint should not be used in stray-current areas. The use of a simplex coupling is optional.

Figure 9 shows two special insulating joints in which the insulation is inserted between the flange of a valve and the flange of a nipple. This type of joint is used whenever it is impossible or inconvenient to install a standard steel insulating joint.

Pipe Fittings

For additional corrosion protection, any fitting installed in a buried or submerged pipeline, excluding side connections, should be of the same material as the pipeline. The practice at the East Bay District, however, is to use cast-iron fittings on all pipelines less than 16 in. in diameter, regardless of the pipe material. This follows the rule for a cast-iron pipeline but requires that when the fitting is installed in an asbestos-cement or coated-steel pipeline, it must be coated to match the pipeline coating. (Cement mortar is applied when the fitting is installed in an asbestos-cement pipeline.) Cast-iron gate valves must be cement-mortar coated when installed in asbestos cement– or cement mortar–coated steel pipelines, but are left bare or with the factory-applied asphalt coating when installed in bare or dipped and wrapped steel pipelines.

If the cast-iron fitting connects a cast-iron pipeline to another type of pipeline, the fitting need not be coated. Side connections on asbestos-cement pipelines do not need to be of asbestos-cement nor do they have to be coated.

Pipe Penetrations Into Concrete

When a concrete structure encases a bare cast-iron or steel pipe which extends from the structure into the soil, the pipe should be insulated from the soil. This insulation should cover the pipe from a point at least 3 in. inside the concrete to the end of the first pipe length in the soil.

The pipe must be dry and cleaned of dust and dirt, then one layer of polyvinyl chloride-backed pipe wrap is applied.* The tape should have a ½-in. lap and be pulled taut and free of air pockets.

* Scotchrap No. 50, a product of Minnesota Mining and Manufacturing Co., St. Paul, Minn., was used.

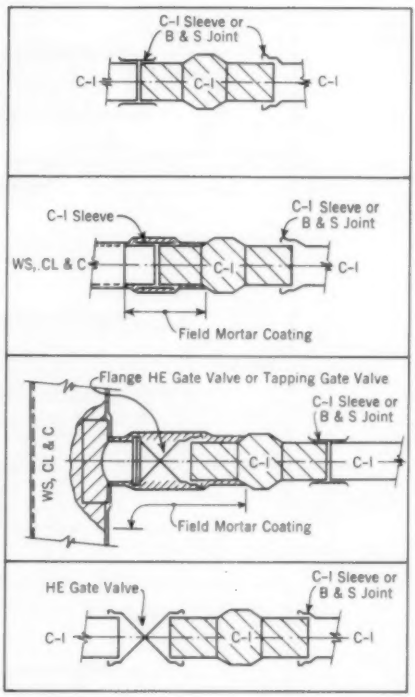


Fig. 7. Installation of Steel and Combination Cast-Iron and Steel Insulating Joint

HE stands for hub end; Flange HE for flanged and hub end. Cement mortar–coated cast-iron pipe is treated as WS, CL & C pipe. Coal tar enamel– or asphalt-coated pipe is considered the same as bare pipe.

Copper Services

Where a copper tubing or red-brass pipe service tap is connected to a steel main, the service should be insulated by the use of a nylon bushing, as shown on Fig. 10. Air and vacuum valves are similarly insulated, as shown in Fig. 11.

The district has adopted the use of nylon insulating bushings for taps up to 1¼ in., which are installed between the main and the main cock, thus isolating the copper service from the

main. Service taps larger than 1¼ in. or services installed without the insulating bushing must be coated as shown in Fig. 12.

If an uninsulated service is installed in a cement mortar–coated main, then the saddle or coupling is coated with mortar to match the main coating. Next, all other exposed surfaces to be coated are wirebrushed free of dirt. Then a single heavy coat of coal-tar enamel * is applied on all sides of the main and the service, 4 ft in each direction from the main cock. In case only a bell hole has been dug, the enamel is applied only to the uncovered part of the main, maintaining a minimum coating of 18 in. each side of the service. If it is necessary to backfill before the coal-tar enamel is dry, the coating should be loosely covered with roofing paper to protect it from damage by the backfill.

Metal Components

Any metal structures or metallic components installed underground or which are submerged must also be protected against galvanic action by applying protective coatings and by proper material selection.

Iron or steel bolts of thin cross section must be coated by hot-dip galvanizing, hot- or cold-applied bituminous compounds, painting, or application of synthetic materials. The field coating usually applied is a ⅛-in. thick coating of rubber adhesive sealer. Nuts and washers must be of the same material as the bolts, and must also be coated.

Brass or bronze nuts or washers must not be used with iron or steel bolts, and steel nuts must not be used with bronze or brass bolts. The same precaution must be used in the selection of dowel or hinge pins such as are used in check valves. Ductile nickel–cast iron, Monel metal, or stainless steel pins should be used when installed in contact with iron or steel.

Bolts which are set in concrete as supports for steel members or galvanized ladders should also be of galvanized steel, Monel metal, stainless steel, or ductile austenitic nickel–cast iron. Two precautions are necessary: [1] stainless steel should not be used in stagnant water, and [2] galvanized steel bolts, washers, and nuts should be given one coat of rubber adhesive sealer after installation. When such bolts are to support copper or brass pipe, the bolts and nuts should be of bronze or silicon bronze, with copper pipe straps. The selection of the proper bolt material for the work is shown in Fig. 13. Brass or bronze bolts should not be used with ring wedge–type anchors having iron spreaders, but should be Portland cement tamped or cast in place. If ring wedge–type anchors must be used, galvanized steel or nickel–cast iron bolts should be substituted for the brass or bronze bolts.

Painting and Coating

Paint is a mixture of a pigment and a vehicle which is applied in thin coats in order for the vehicle to oxidize. Coatings are solutions of heavy materials in a solvent or thinner which are thickly applied, the thinner evaporating after application. Some coatings are heated to get a thin consistency for application and they reharden when cooled.

Painting or coating is the oldest and most widespread means of combating corrosion, but no single paint is a cure-all. Protective coatings must be selected to suit the particular corrosion conditions affecting the structure to be protected.

The first and most important step in painting is surface preparation. The surface must be clean and dry, because

* Bitumastic 50, a product of Koppers Co., Inc., Pittsburgh, Pa., was used.

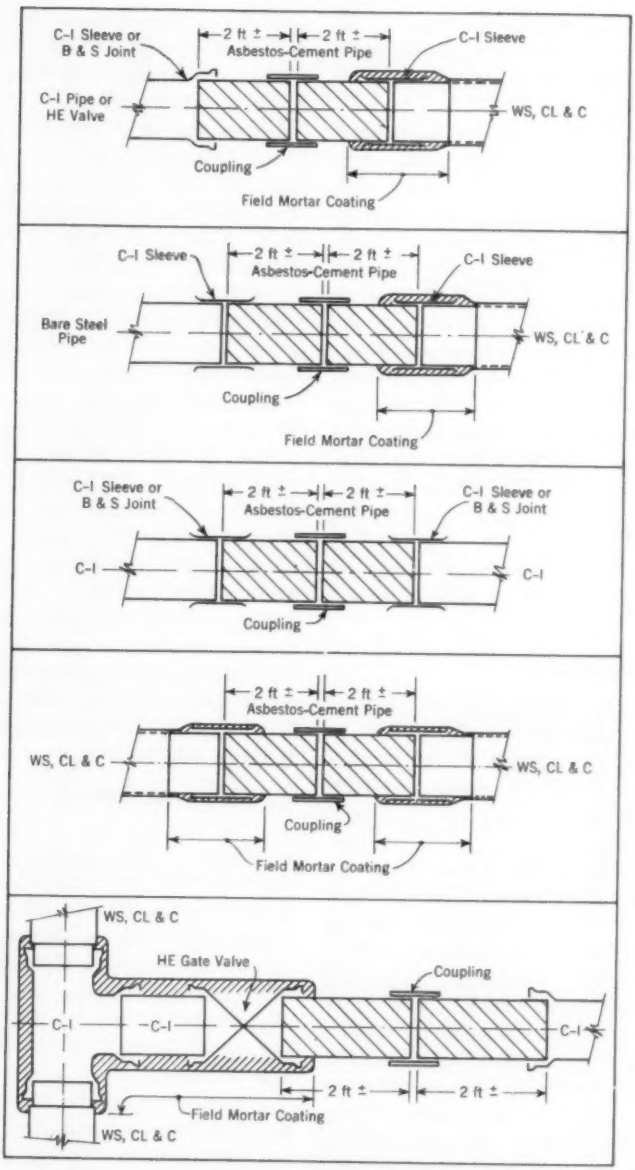


Fig. 8. Asbestos-Cement Pipe Insulating Joints

Cement mortar-coated cast-iron pipe is treated as WS, CL & C pipe. Coal tar enamel– or asphalt-coated pipe is considered the same as bare pipe.

paint cannot give good service if it is applied over a dirty, greasy, or wet surface.

The second step in painting is proper mixing of the paint. The manufacturer's instructions should be carefully followed, because inadequately mixed or improperly thinned paint will give greatly reduced protection. Paints of good quality give satisfactory results because the manufacturer has properly proportioned the pigment and vehicle.

For priming metal structures exposed to air or moisture, a mixture of linseed oil and either zinc chromate or red lead should be used. Both these pigments are rust inhibitors. For quick drying, a phenolic vehicle can be substituted for the linseed oil.

Aluminum pigment gives excellent protection to weathering when used as a finish coat. The pigment is bought in paste form and mixed with a varnish as needed on the job. There are government specifications describing the paste and mixing of varnish.

Vinyl-resin paint gives a hard, smooth, and tough film which is inert to water and many chemical solutions. It has excellent resistance to sunlight. For good underwater protection the paint film should be about $\frac{1}{32}$ in. thick.

Coal-tar enamel and asphalt coatings are used extensively to protect submerged or buried iron or steel. Hot-applied coal-tar enamel gives good protection when properly applied and used according to the manufacturer's recommendations. It is not recommended for exposure to weather, because sunlight causes it to sag and subfreezing temperatures make it brittle.

Cold-applied coatings are used on metal structures in vaults and other accessible locations where maintenance painting is possible. The rubber adhesive sealer used by the district can be either brush or spray applied. It is thinned with white (non-leaded) gasoline. Since thinners are volatile and inflammable, adequate fire precautions must be taken at all times. When rubber adhesive sealer is applied by means of a spray gun, 25–50 psi fluid pressure and 60–70 psi atomization should be used. The coating will be dry to touch in about 10 min, firm after 2 hr, and thoroughly dry in 48 hr. The coating is applied about $\frac{1}{8}$ in. thick. Backfilling may be done after 2 hr of drying.

Bonding

Bonding is the second general method of corrosion prevention. It is used to combat electrolysis. When stray electric currents flowing between adjacent pipelines or structures develop unsafe voltages, a copper cable bond is installed to provide a low-resistance path for the current and to reduce the voltages to safe values. Bonds are connected to steel pipe by welding or brazing. The cable may be connected directly to the pipe or to a piece of angle iron which has been previously welded to the pipe. Details

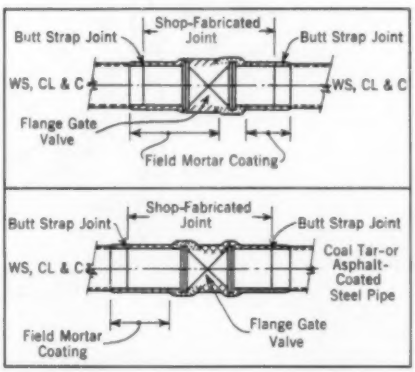


Fig. 9. Special Insulating Joints

Cement mortar–coated cast-iron pipe is treated as WS, CL & C pipe. Coal tar enamel– or asphalt-coated pipe is considered the same as bare pipe.

of these connections are shown in Fig. 5, 14, and 15.

Since bonding cables are frequently severed during street excavation work, a test point is installed by routing a cable from each side of an insulating joint to a manhole or curb box, as shown in Fig. 14. A removable jumper is connected across the cable

For precast concrete pipe, the test connection is installed as shown in Fig. 15, breaking out concrete at the pipe end, making the necessary welds, and then restoring the concrete. The nipple is coated and filled as shown. If a lead gasket is used instead of the rubber gasket, the bonding cables across the joint are omitted.

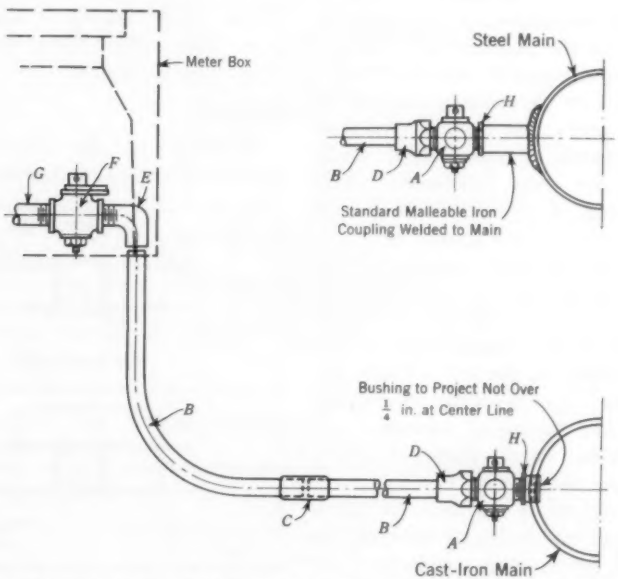


Fig. 10. Nylon Insulating Bushing Installed in Typical Service

Typical connections are shown for steel and cast-iron mains. Keyed letters, for both connections, indicate: A—*main cock;* B—*copper pipe;* C—*coupling, copper to copper (for joints only);* D—*adapter (nipple with inside thread);* E—*elbow, copper to iron;* F—*curb cock;* G—*brass meter coupling; and* H—*nylon bushing.*

ends, and periodic current measurements show if the bond is functioning.

Test connections on steel pipe are made at exposed field joints, as shown in Fig. 14. The nipple on the main is coated to match the main coating, using Portland cement mortar for cement mortar–coated pipe and enamel for coal tar–enameled pipe.

Bonding connections to the lead sheaths of underground cables are made to existing cross-bonds in manhole structures or to special terminals provided by the corporation owning the cable.

Sleeve-type couplings, as shown in Fig. 16, must also be bonded in order to insure a continuous metallic circuit.

On cement mortar-coated steel pipe, sufficient mortar coating is removed to braze the flattened copper tubing to both pipe ends and the coupling. The tubing and brazings are then coated to a thickness of at least $\frac{1}{8}$ in. with adhesive. A wire mesh is fastened around the entire coupling assembly and sufficient cement mortar is applied to cover all metal to a minimum depth of $\frac{3}{4}$ in.

For dipped and wrapped steel pipe, the same procedure is used, omitting the wire mesh and mortar coating. In lieu of the district's regular rubber adhesive sealer, a heavy coal-tar enamel may be applied, using a primer coat on all bare metal and allowing it to dry for 24 hr. The final coat of enamel is poured into a form built around the bonding jumper so that at least a 1-in. cover is obtained over and on each side of the jumper.

For cast-iron pipe, standard $\frac{3}{4}$-in. main cocks are installed by a tapping machine, using salvaged cocks whenever available. Soft $\frac{3}{4}$-in. copper tubing is connected to these main cocks, and tubing, cocks, and couplings are coated with at least $\frac{1}{8}$ in. of rubber adhesive sealer. Because the upper tubing and main cocks are used instead of a bonding cable, plastic insulating bushings between the main cocks and pipe are not used.

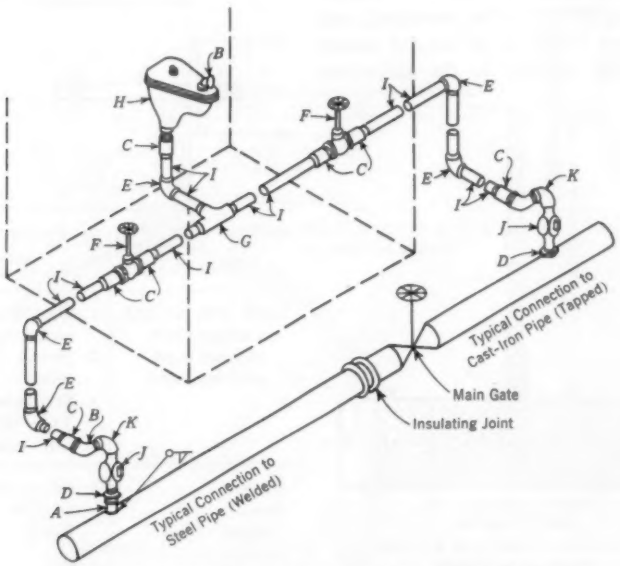


Fig. 11. Nylon Insulating Bushing Installed in Air Valve Connection to Main Gate

The keyed letters indicate the following: A—*2-in. wrought-iron coupling;* B—*brass 90-degree street elbow;* C—*coupling, copper to iron;* D—*nylon bushing;* E—*elbow, copper to copper;* F—*bronze gate valve, rising stem;* G—*tee, copper to copper to copper;* H—*air and vacuum relief valve;* I—*copper pipe;* J—*chabot cock; and* K—*plain 90-degree elbow, brass.*

Cathodic Protection

Cathodic protection (forced drainage) is the third method of corrosion protection applied to buried structures and pipelines. A cathodic-protection station is a direct current source such as a d-c generator or rectifier. The positive terminal of the station is connected to electrodes which are buried near the structure to be protected, and the negative terminal of the d-c source is connected directly to the structure.

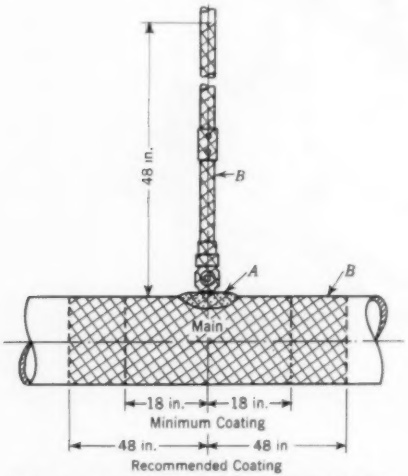


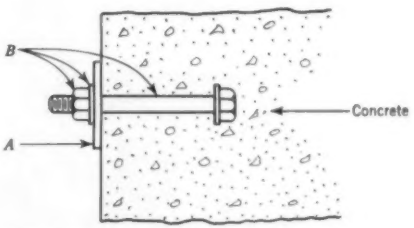
Fig. 12. Insulating Coating Applied to Service When Insulating Bushing Is Omitted

The keyed letters indicate the following: A—*mortar coating on saddle;* B—*coal-tar enamel coatings.*

The electrodes can be iron, carbon, or graphite, the choice depending on cost and availability. The cathodic-protection station forces the electric current into the ground through the electrodes, from the ground to the structure, and then back to the station through the negative terminal. The current forced into the pipe or structure from the ground neutralizes the galvanic current flowing from the structure into the ground. If the protection current is greater than the galvanic current, a hydrogen film is formed on the pipe which prevents corrosion.

Because the cathodic-protection current flows from the electrodes, they act as sacrificial anodes and disintegrate. Iron electrodes disappear at a rate of 20 lb per ampere per year (8,760 amp-hr). By comparison, 20 lb of graphite will last 400,000 amp-hr.

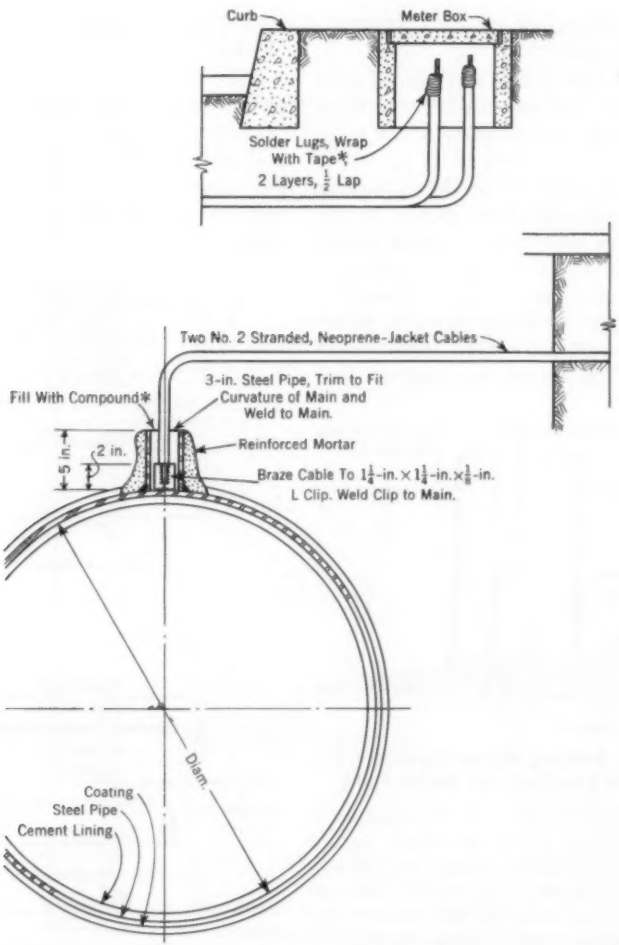
Cathodic protection can also be applied by using galvanic anodes (usually magnesium, but sometimes aluminum or zinc). A d-c source is not required, since the magnesium is anodic to iron or steel and generates a galvanic current. One pound of magnesium can generate 997 amp-hr. On large struc-



Material *A*	Material *B* (in order of preference)
Cast iron or galvanized steel, painted steel, stainless steel	1. Ductile austenitic nickel cast iron 2. Monel (Type *K*, hot-rolled) 3. Stainless steel (AISI* Type 303) 4. Galvanized steel
Bronze Brass Copper	1. Silicon bronze (ASTM B98 alloy-*D*-hard)
Aluminum Aluminum alloy	1. Galvanized steel 2. Plain steel 3. Aluminum alloy

* American Iron and Steel Inst., New York, N. Y.

Fig. 13. Selection of Bolts, Nuts, and Washers for Immersed or Moist Atmospheric Conditions


Curb
Meter Box
Solder Lugs, Wrap With Tape*, 2 Layers, ½ Lap
Two No. 2 Stranded, Neoprene-Jacket Cables
3-in. Steel Pipe, Trim to Fit Curvature of Main and Weld to Main.
Fill With Compound*
Reinforced Mortar
2 in.
5 in.
Braze Cable To 1¼-in.×1¼-in.×⅛-in. L Clip. Weld Clip to Main.
Diam.
Coating
Steel Pipe
Cement Lining

* The tape used was Scotch No. 33, a product of The Minnesota Mining and Manufacturing Co., St. Paul, Minn. The insulating compound used was Ozite "B", a product of G & W Electrical Specialty Co., Chicago, Ill., or equivalent.

Fig. 14. Bond Test Connections for Welded Steel, Cement Mortar–Lined and –Coated Pipe

tures or aqueducts which require large currents, magnesium anodes will not give complete protection economically, and a d-c source must therefore be used.

Pipeline Selection

In pipeline design, some corrosion protection can be obtained by proper selection of the type of pipe to be installed. This selection should be based on data from soil surveys made along the proposed pipeline route. In good soils it is safe to use cast-iron pipe. For bad soils, either asbestos-cement pipe, coal tar–enamelled pipe, or cement mortar–lined and –coated steel pipe is

suitable, depending on the expected service pressure.

In very bad soils, such as ground filled from factory wastes or mine dumps, it may be necessary to use plastic pipe.

In the application of the foregoing rules, certain procedures should be followed. For example, a typical design problem is shown in Fig. 17 where a reservoir supplies an area through a 3-mile long welded-steel pipeline, which has been lined and coated with cement mortar. The area to be supplied contains a cast-iron distribution system, and is subject to stray currents from a street railway system.

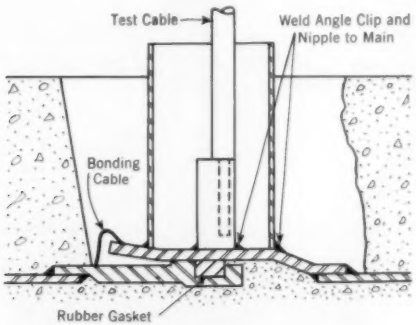


Fig. 15. Bonding Cables Installed on Concrete Pipe Bell and Spigot Joint

The bonding shown is to be used only in stray-current areas on rubber gasket joints. Two 250,000-circular m. Railway bonding cables are each welded between spigot and bell near the top center line and painted with coal-tar enamel.

As soon as the reservoir location and pipeline route are known, a soil resistivity survey is made. This survey shows the reservoir soil area to be good. About 1 mile below the reservoir, the soil around the pipeline changes rapidly from good to bad. At about 2½ miles below the reservoir, the soil changes gradually from bad to good. The resistivity changes show where insulating joints should be installed to stop galvanic currents in the pipeline.

The soil under the reservoir will have a low oxygen content, while that around the pipeline is better aerated and will thus have a much higher oxygen content. Because of this difference in oxygen concentration, a galvanic current could flow between the pipeline and the reinforcing steel of the reservoir. To stop this current an insulating joint is installed in the pipeline at the reservoir. An impervious membrane under the reservoir, such as a bituminous coating, would further insulate the reservoir.

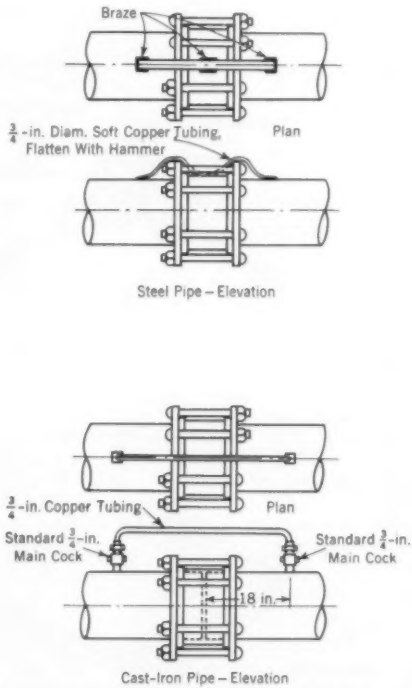


Fig. 16. Bonding Jumpers Installed on Sleeve-Type Couplings

Tubing can be brazed to coupling in cast-iron line, although heat may cause the cast iron to crack.

Where the pipeline is in good soil, the cement-mortar coating will give

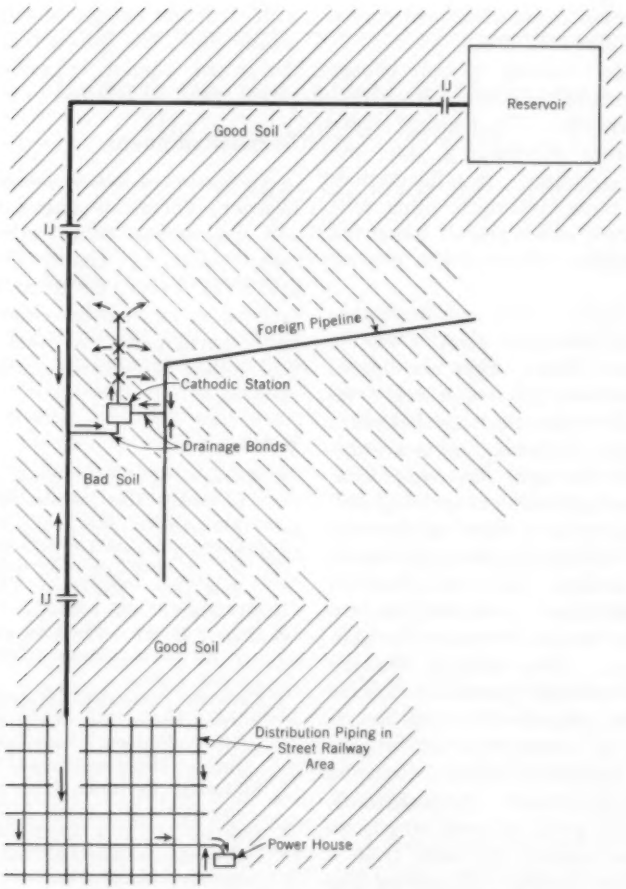


Fig. 17. Anticorrosion Measures Incorporated in Pipeline Design

The arrows indicated the direction of current flow. IJ stands for insulating joint.

adequate corrosion protection. An insulating joint should be installed at the boundary between good and bad soils, however. This joint will stop the flow of galvanic current between the pipeline section in the well-aerated good soil and the section in the poorly aerated bad soil. The insulating joint at the 2½-mile point acts in this way, preventing flow of the galvanic current from the pipeline section in the town area (good soil) along the pipe to the section in the bad soil area. If these two insulating joints were omitted the pipeline currents flowing into the bad soil area would discharge into the soil, thus corroding the pipe. The corrosion products (rust) building up under the cement-mortar coating would eventually crack the coating loose from the pipe, and then a secondary action, between the coated- and uncoated-pipe

sections, would cause additional corrosion of the uncoated areas.

The street railway system causes stray currents to flow in the town distribution system. To prevent these currents from discharging into the ground, a continuous metallic system is built by cross-bonding to other utility structures, which are all connected to the negative return of the electric railway.

With these corrosion-protection measures included, the pipeline can be designed and built. After the line is placed in service, a series of field tests will show its exact electrical behavior. Even though insulating joints are apparently in the most favorable locations, a small galvanic current may still be discharging to ground in the bad soil area. Cathodic protection would then be installed near the point of greatest discharge, protecting the entire pipeline section between the insulated joints. The current, flowing from the cathodic protection station through the ground to the pipeline, is supposed to return to the station through a metallic connection from the pipeline to the station. Stray currents, however, will go to adjacent structures in the same manner as those from a street railway system. To reduce this effect, the station is adjusted for a minimum of these "interference currents" on the other structures. It may be necessary to install a cross-bond between the other structures and the cathodic station to return those stray currents to their source.

Summary

Corrosion of metallic water works structures is a costly process which operates unceasingly. It is wasteful of materials, man-hours, and water. The East Bay Municipal Utility District, however, by means of a corrosion-control program which is integrated with structure design, installation, and maintenance, has shown that, although this waste cannot be entirely eliminated, it can be reduced to a minimum.

Acknowledgment

This paper is based on the East Bay District's corrosion-control experience and represents data collected over many years by David Hendrickson and Fred Terry, electrical technician, assisted by many other employees who have participated in this program. The author extends his gratitude to all of them.

References

1. *Manual on Underground Corrosion.* Columbia Gas Service Corp., New York, N.Y. (1952).
2. Hendrickson, David & Hertzberg, Lee B. *Manual on Corrosion Control.* East Bay Municipal Utility Dist., Oakland, Calif. (1954).
3. Uhlig, H. H. The Cost of Corrosion to the United States. *Corrosion,* **6**:29 (Jan. 1950).
4. Cathodic Protection. Report of Correlating Committee on Cathodic Protection. National Assn. of Corrosion Engrs., Houston, Tex. (1951).
5. Editorial. Corrosion Losses. *Corrosion Prevention & Control,* **1**:271 (1954).
6. Denison, I. A. & Ewing, S. P. Corrosiveness of Certain Ohio Soils. *Soil Science,* **40**:287 (1935).
7. Logan, K. H.; Ewing, S. P.; & Denison, I. A. Soil Corrosion Testing. Symposium on Corrosion Testing Procedures. ASTM, Philadelphia, Pa. (1937).
8. Uhlig, H. H. *Corrosion Handbook.* John Wiley and Sons, Inc., New York (1948). p. 466.
9. Kulman, F. E. Microbiological Corrosion of Buried Steel Pipe. *Corrosion,* **9**:11 (Jan. 1953).
10. Deuber, C. G., The Present Status of Bacterial Corrosion Investigations in the United States. *Corrosion,* **9**:95 (Mar. 1953).
11. Beckwith, T. D. & Bovard, P. F. Bacterial Disintegration of Sulfur-containing Sealing Compound in Pipe Joints. *Pub. Biol. Sci.,* **1**:121 (1937).

Report on the Effect of Iron on High-Capacity Zeolite

Edgar G. Will

A paper presented on Sep. 22, 1955, at the Ohio Section Meeting, Columbus, Ohio, by Edgar G. Will, Chief Chemist, Div. of Labs., State Health Dept., Columbus, Ohio.

THE water treatment plants selected for the present survey were zeolite water-softening plants having the following features: [1] the well water contains a considerable amount of iron; [2] there is no pretreatment of water for removal of iron before the water passes through the zeolite softening units; and [3] the units are equipped with resin-type zeolite having a high exchange capacity. At all these plants, iron removal devices are provided for the water bypassed around the softening units. At three of the plants, regeneration of the units is automatically controlled, and it is manually controlled at the other three plants. At five of the plants the zeolite units are downflow pressure units. At one plant the zeolite units are upflow gravity units. Supervision seemed adequate at all of the plants.

The study described here was to determine the efficiency of high-capacity zeolite to remove iron by base exchange and to determine the effects of iron on the exchange capacity of the zeolite.

Types of Units

By base exchange, zeolite can remove iron in solution only. Until the water is exposed to oxygen, the iron present in a well water is ferrous iron. It is important that the iron be kept in the ferrous state until the water passes through zeolite units. Such factors as excessive drawdown, leaking pumps, and intermittent pumping, however, can introduce air into the water and oxidize a portion of the ferrous iron into ferric iron. In downflow zeolite units the ferric iron can be partially removed by filtering action. The high-capacity zeolites, however, are coarser than the greensand zeolites formerly used and do not provide as efficient filtering action.

Table 1 shows that the zeolite units are usually effective in removing the iron from the water.

Treatment

Although the zeolite is effective in removing iron from the water, it appears, at least at some plants, that brine regeneration of the zeolite does not remove all of the iron from the zeolite. Some iron remains, coating or penetrating the zeolite particles. This results in a gradual decrease of the exchange capacity of the zeolites, which may drop to as low as one-third of the original exchange capacity. Obviously, when this occurs, action must be taken to restore the zeolite to its original capacity, if possible.

The firms furnishing the resin zeolites recognize the troubles which

TABLE 1

Effectiveness of Zeolite Units

Plant	Iron Content—*ppm*			
	Raw Water		Zeolite-softened Water	
	Ferrous	Ferric	Ferrous	Ferric
Groveport	2.6	0.08	0.17	0.01
Grove City	1.95	0.23	0.03	0.39
Mechanicsburg	2.2	0.01	0.08	trace
Mt. Gilead	1.35	trace	0.03	0
Lodi	1.6	0.06	0.15	0.03
Cuyahoga Falls	1.9	0.36*	0.02	0.01

* Average from four wells.

may be caused by iron. Where the iron content is high, they generally recommend that the iron be removed before the water is passed through zeolite units. Some firms recommend acid treatment to restore the exchange capacity of zeolite which has become fouled with iron. Others recommend treatment with 1 lb sodium hydrosulphite per cubic foot of zeolite. Others suggest application of polyphosphates to the raw water to prevent or retard the deposition of iron on the zeolite.

Plant *A*

At Plant *A* the zeolite was said to be originally rated at 26.5 kilograins (kgr) per cubic foot. However, at the end of 1 year's operation, treating water having an iron content of 1.6 ppm, the capacity had decreased to 8.7 kgr per cubic foot, or to about one-third of its original capacity. After special treatments by plant operators, the exchange capacity had been increased to 19 kgr per cubic foot, which was the capacity at the time of inspection.

Laboratory tests on used zeolite from Plant *A* were made at the Central Laboratory of the Ohio Department of Health. In order to obtain the maximum exchange capacity, this zeolite was regenerated during the laboratory test runs using 25 lb of salt per cubic foot of zeolite. For an exchange capacity of 19 kgr per cubic foot, this is equivalent to 1.3 lb per kilograin of hardness removed. In plant operation, 0.25–0.45 lb of salt are required per kilograin of hardness removed. In the laboratory tests, an effort was made to obtain the maximum exchange capacity of the zeolite regardless of the amount of salt required for regenerating. It was found that by using 25 lb of salt per cubic foot of zeolite the maximum exchange capacity was attained and additional use of salt did not increase the exchange capacity.

Plant *A* zeolite was evidently badly fouled with iron. Hydrochloric acid was recommended by the manufacturer for cleaning this zeolite. This was tried, using a 10 per cent solution, 6.3 lb of HCl per cubic foot, with a 30-min run and a backwash. It was then regenerated with salt. The capacity of this zeolite was thus raised from 19 to 30 kgr per cubic foot. Repeated acid treatment gave no further improvement. The bed was considered to have

reached its maximum capacity. It is evident that HCl will restore the capacity of this zeolite.

Ferric and aluminum ions are readily adsorbed but are not so readily removed during regeneration with brine. Because of the many forms in which iron and aluminum can exist in water, one method may not solve the problem on all waters. There may be iron carbonate, iron bicarbonate, iron sulfate, iron phosphate, or others. It may be ferrous iron, usually soluble, or ferric iron which may be insoluble. The change from ferrous to ferric may take place in the water or on the surface of the zeolite or in the lattice framework of the zeolite material itself. There may be colloidal iron which may pass through the bed unchanged or may deposit on the grains. Too often, zeolite is thought of as sand, but, although it may act like sand in filtering out large particles, in removing hardness and iron each grain has the texture of a sponge and all parts of the zeolite particle act to remove the iron. One can imagine the effect of this combined iron changing to an insoluble form—changing to a ball of iron, in effect. On regeneration, several layers of iron are removed, but the interior remains, thus lowering the efficiency of the grain. Treatment with chemicals works only when the chemicals penetrate to the center of the grain, and the larger or denser the grain, the slower the chemical methods work.

In order to show the effect of iron, a raw water containing 4 ppm ferrous iron and 300 ppm hardness was passed through Plant *A* zeolite until 5 ppm of hardness showed in the effluent. Six runs reduced the capacity from 30 to 19 kgr per cubic foot. It is true that high-capacity zeolite will remove up to 0.5 ppm of iron, but with water of 2 ppm of iron or more, the iron may not be completely cleaned from the zeolite grains by regeneration of the zeolite with salt. Iron may exist in water supplies as ferrous or ferric hydroxide or hydrated oxide. Soluble iron, either ferrous or ferric, is readily exchanged for sodium. Any change to an insoluble form, however, fixes the iron in the zeolite and this prevents removal by sodium and thus lowers the capacity of the bed.

As a summary, because of the porous nature of the zeolite, it is relatively easy to clog up the interior portion of the grain. Once filled up, these pores are hard to clean and the iron remains unchanged when attempts are made to clean the bed. This may account for differences observed in different plants and with different types of zeolite. A difference in the types of water and a difference in the porosity of the zeolite all tend to make the picture confusing. It must be noted, too, that the iron is not all laid down on the surface of the grain to be easily washed off by backwashing, but is also adsorbed by the interior of the grain.

After proving definitely that the iron was causing the lowered capacity of the softening beds, attempts were made to find a cure.

In order to note the effect of addition of polyphosphate to the raw water, this zeolite was cleaned with 10 per cent hydrochloric acid and regenerated with salt. It now showed a capacity of 30 kgr per cubic foot. A run was then made using the raw water containing 4 ppm ferrous iron which had previously fouled the zeolite and 4 ppm polyphosphates. This gave an exchange capacity of 27.9 kgr per cubic foot. On repeating the run several times, there was no further loss of ca-

pacity. This clearly indicated the value of polyphosphates as a preventive of fouling by iron. The amount of polyphosphates used may have been excessive for the amount of iron present. No attempt was made at this time to determine the minimum amount of polyphosphates necessary.

The bed was again fouled by making a run using ferrous and ferric iron and then regenerating with salt. It now gives a capacity of 19 kgr per cubic foot. A 1 per cent solution of sodium hydrosulfite was used as a regenerant followed by a salt regeneration. This iron reduction treatment raised the capacity of the zeolite to 27.9 kgr per cubic foot.

The tests show that, at this plant, which had been having difficulty, relief could have been obtained by: [1] washing with 10 per cent hydrochloric acid followed by salt regeneration; [2] washing with a 1 per cent solution of sodium hydrosulfite; or [3] treating the raw water with polyphosphate before softening. These treatments, however, will not apply in all cases, as will be shown.

Plant *B*

At Plant *B* where a different zeolite was used and an upflow open bed–type of treatment, there were other problems. Inspection was made and samples of raw water and effluents were collected and analyzed. A portion of the used zeolite from this plant was collected and used for the laboratory research.

The raw water at Plant *B* sometimes ran as high as 4 ppm total iron with an appreciable amount of ferric iron present. Open rectangular concrete beds using upflow and surface draw-off were used in this plant. Each bed contained 480 cu ft of zeolite and the plant was being operated in an acceptable manner. The zeolite originally had a rated capacity of 30 kgr per cubic foot and had been in use 2½ years. Regeneration was manual. The zeolite had been treated with sodium hydrosulfite once each year. For 3 months, 4 ppm of sodium polyphosphate had been added to the raw water ahead of the softeners. This was reduced to 2 ppm for 30 days. The beds were now running at one-half the original rated capacity.

In the laboratory, this zeolite was first regenerated with salt and the capacity was found to be 14 kgr per cubic foot. It was badly fouled with iron, and it was therefore treated with a 1 per cent solution of sodium hydrosulfite and then regenerated with salt. This did not help, so a second treatment of hydrosulfite was left in the bed overnight. After regeneration, the capacity was still found to be 14 kgr per cubic foot. It was therefore concluded that the hydrosulfite had no effect on removal of iron from the zeolite. Its only effect might be a reduction of ferric iron to ferrous iron. This zeolite was now washed with 10 per cent HCl, then regenerated with salt. The capacity rose to 16 kgr per cubic foot. The acid wash was repeated and the capacity increased to 19 kgr per cubic foot. A third acid wash raised the capacity to 23 kgr per cubic foot, where it remained despite several more acid washes followed by regeneration. At this stage, it was thought that oxidation may have occurred, so a wash with 2 per cent sodium hydrosulfite, followed by 10 per cent HCl, then salt regeneration, was tried. This procedure raised the capacity to 26 kgr per cubic foot.

The hydrosulfite merely reduces the iron to the ferrous form, in which state

it can be removed more easily by acid or salt. Perhaps a tighter molecular structure is present in this zeolite. It is to be noted, also, that this zeolite also has a larger effective size than the zeolite in Plant *A*. Both of these facts might account for the slower action of the acid and the hydrosulfite.

It was of interest to note that one run with 4 ppm of soluble ferric chloride plus calcium hardness lowered the capacity of the zeolite from 26 to 18 kgr per cubic foot. This iron was in solution. In order to determine the effect of polyphosphates on soluble ferric iron, a run was made using 4 ppm soluble ferric iron and 4 ppm polyphosphates. No loss in capacity was noted. After regeneration with salt, this run was repeated several times with no loss in capacity.

Conclusion

From the above results on two failing zeolites, it appears that, in ordinary plant operation, iron in excess tends to remain in the zeolite and lowers its capacity. Sodium hydrosulfite will sometimes reduce the iron and allow its removal with salt regeneration. Treatment of the zeolite with 10 per cent HCl, followed by salt regeneration, may return the zeolite to its original capacity, but these measures are not preventative. It has been shown, however, that proper dosage of polyphosphates in the raw water will prevent retention of iron and fouling of the beds by iron retention. The other alternative always recommended by those selling zeolites is to remove the iron by aeration and filtration before softening.

Friction Losses in Service Lines and Fittings

Gerald E. Arnold

A paper presented on Apr. 5, 1956, at the Pennsylvania Section Meeting, Philadelphia, Pa., by Gerald E. Arnold, Gen. Supt., Water Dept., Philadelphia, Pa.

IN considering the provision of water service to consumers' premises, attention should be given to minute-by-minute demand rates, particularly in residences. A steady increase in water consumption per capita has been evidenced for a number of years. Between 1920 and 1950 the per capita use of water in this country increased from 100 to 140 gal. By most of the water works industry this gradual but steady increase is expected to continue, requiring larger facilities to produce and deliver increasing quantities of water for all consumers.

The rapid increase in water consumption in domestic residences in the past 4–5 years has introduced a new dimension to the problem of determining the adequacy of service lines and fittings between mains and residential piping. The number of water-using fixtures has steadily increased and will continue to do so; each of these fixtures requires an adequate volume of water at a satisfactory pressure to supply consumers' demands.

In the past, demand rates for ordinary dwellings have been in the range of 5–6 gpm. This is commonly accepted as the normal consumption when two fixtures are running at the same time. Because of the widespread use of automatic washing machines, air-conditioning units, garbage grinders, dishwashers, and similar devices, however, demand rates are now approaching 12–15 gpm.

Recent studies have provided the following average flow rates for various water-using fixtures and appliances: laundry tub, 5 gpm; toilet tank, 4 gpm; kitchen sink, 4 gpm; bathtub, 4 gpm; shower, 3 gpm; lawn sprinkler unit (hose and single sprinkler), 6 gpm; wash basin, 3 gpm. If all these fixtures were operated simultaneously, the total flow required to supply them would be 29 gpm.

Leonard N. Thompson, of the St. Paul, Minn., water system, has reported some consumption rates for similar fixtures which are much higher than those given above (*1*). If all seven fixtures were operated simultaneously at the rates reported by Thompson, the flow would be 43 gpm. For the purpose of the computations involved in the present article, 29 gpm will be used. Obviously, the likelihood of all seven fixtures being used at one time is remote.

A review of the reports of several different investigators (*2*) indicates that the water requirements of an automatic washing machine are 5 gpm, with a required residual pressure of 20 psi. (The importance of this residual pressure figure will be apparent later.) Manufacturers of dishwashers declare that their products will use about 1 gpm; some reports, however, have indicated requirements as high as 5 gpm. For these computations, the decidedly conservative figure of 2 gpm will be used. Garbage

grinders required 2.5–4 gpm, depending upon the model used; for the present purpose, 3 gpm will be considered the average rate.

Air conditioning is becoming an increasingly important factor in water supply requirements. The Air Conditioning and Refrigeration Institute advises that air-conditioning units of greater than 2 tons capacity must be water-cooled; and no manufacturer has yet produced a satisfactory air-cooled unit of that size. Water consumption for air conditioning averages about 2 gpm per ton of refrigeration capacity. The ordinary window-type air conditioner has a capacity of about ¾ ton and can effectively cool one or two domestic rooms of average size. To properly cool a five- or six-room house would require a unit with a capacity of about 3 tons. With water consumption at the rate of 2 gpm per ton, the water demand for a 3-ton domestic unit would be 6 gpm. For units of this size, operating in the summertime only, the use of such water-conserving devices as cooling towers is not economical.

Using 5 gpm for an automatic washing machine, 2 gpm for a dishwasher, 3 gpm for a garbage grinder, and 6 gpm for an air conditioner requires a total flow of 16 gpm. Adding this to the flow rate of 29 gpm established previously for normal fixtures gives a total water consumption rate, for all eleven fixtures operated simultaneously, of 45 gpm.

As previously observed, the likelihood of all these units being used at once is remote; the use of any three devices at one time, however, will require a flow rate of 12–15 gpm. It is not at all unreasonable that a lawn sprinkler, an air conditioner, and a bathtub might be operated at the same time; or that an automatic washing machine, a kitchen sink, and a toilet might be used simultaneously. It seems, therefore, quite clear that the efforts of the water works industry to serve domestic consumers should be based on demand rates of approximately 12–15 gpm.

In the electric-power industry it has frequently been observed that the number of electrical devices used in homes has increased rapidly. In 1930 nineteen major types of electrical appliances were manufactured for domestic use. In 1940 this number had increased to 33; in 1950, to 40. By 1955, 56 different electrical appliances were manufactured for domestic use, and the number is still increasing. The electric power industry is stressing the importance of adequate wiring to meet these demand rates and is recommending the installation of 100-amp wiring to supply these devices in homes. The water works industry should give similar consideration to the service piping and fittings needed to supply adequately the increasing needs of residential consumers.

In addition to consideration of flow rates approximating 15 gpm, study should be given to changing pressure characteristics as water flows at these rates through service lines from the main into residential piping. For the purpose of this discussion, the author has used a standard ¾-in. service line with ¾-in. fittings and a ⅝-in. water meter, which is fairly typical of ordinary domestic service installations. Careful head loss studies of the service-line devices were made in the meter shop of the Philadelphia Water Department, using a mercury manometer to determine the loss of head at various flow rates through each device. The author conducted these tests personally and believes them to be accurate.

Head Loss Studies

The first device through which the water must pass on leaving the street main is the corporation stop. (At the Philadelphia works this device is called a ferrule.) Curve *A* of Fig. 1 shows the head loss at flow rates of 5–20 gpm. It will be noted that at the 15-gpm rate the head loss is nearly 2 psi.

The next device through which the water must flow is the curb stop. On Curve *B* of Fig. 1 it may be observed that the normal curb stop without improvements has a head loss of nearly 2 psi at a 15-gpm rate of flow.

Next, the water must pass through the service line. In Philadelphia, the average length of water service line from main to house piping is 60 ft. For purposes of this test, 60 ft of new ¾-in. Type K copper tubing was used. These head losses were actually determined in a flow test and were checked by means of the Hazen-Williams formula using a coefficient of 140. As shown by Curve *A* of Fig. 2, the head loss through 60 ft of ¾-in. pipe at a rate of 15 gpm is 24 psi.

After passing through the service line, the water must pass through a valve or stopcock situated just ahead of the meter. The common practice is to use a globe valve at this point. At 15 gpm, the head loss through a standard globe valve is slightly more than 4 psi (*see* Fig. 1, Curve *C*).

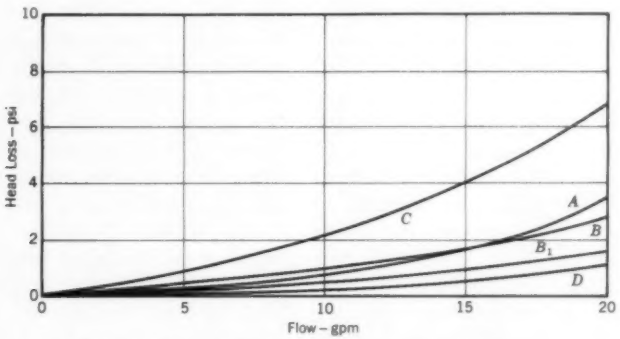


Fig. 1. Loss of Head Through Stops and Valves

Head losses through the following types of stops and valves are shown:

Curve A, ¾-*in. corporation stop or ferrule;*
Curve B, ¾-*in. curb stop;*
Curve B_1, *improved curb stop;*
Curve C, ¾-*in. globe valve;*
Curve D, ¾-*in. gate valve.*

The next device is the water meter itself. The solid-line curves in Fig. 3 demonstrate the head loss through six different models of water meter. For the purpose of this computation, the middle curve shows a head loss of 6 psi at a 15-gpm rate. (The letters *A–F* on the chart represent meters of different manufacture.)

Adding these factors together, including only the corporation stop, the

curb stop, 60 ft of copper tubing, a globe valve, and a water meter, the total head loss at the beginning of the house piping is found to be 38 psi at a flow rate of 15 gpm (*see* Fig. 2, Curve *B*). All of the devices used in this study were new. There were no corrosion products present, nor was there clogging of any of the openings. In general, the conditions of these tests might be described as ideal. With a pressure of 30–40 psi in the street main, as is common in many cities, it is easy to see that flow rates of 15 gpm are impossible. The consumer suffers inadequate water pressure and usually complains to the water department when he is unable to get water upstairs while water-using fixtures are being employed downstairs.

Additional pressure losses are likely to be encountered, as most installations involve other devices which produce still greater head loss. Curve *A* of Fig. 4 shows the head loss through two ⅝-in. meter connections with a ¾-in. spacer pipe in place of the meter. At the 15-gpm rate, the head loss is nearly 3 psi.

Where a meter must be installed in vertical piping, the use of a horn or similar device is required. Curve *B* of Fig. 4 shows the head loss through a ¾-in. meter horn without the use of a valve. At 15 gpm, the head loss through the horn is 4 psi.

As mentioned before, these tests were made with new equipment. For purposes of comparison, an old meter that had been brought into the meter shop in regular rotation was tested for head loss before repair. This meter was still operating and was registering at a flow rate of 0.25 gpm. In Fig. 4, the head loss for this type of meter when new is shown as Curve *C*. The head loss for the old meter is represented by Curve C_1. It will be noted that the head loss of this old meter at 15 gpm was 13 psi.

If 4 psi for a horn and 7 psi for an old meter are added to the head loss Curve *B* in Fig. 2, the total head loss for a full service line, with fittings, is 48 psi at 15 gpm, as shown by Curve *C*.

Head loss studies were made of a standard meter horn for vertical piping, with and without a valve, as well as for ¾-in. galvanized-iron piping with standard elbows. In Fig. 4, the head loss of the bare horn is shown as Curve *B*. Curve B_1 shows the head loss with the use of standard galvanized-iron piping and four standard elbows (without any valve). Curve B_2 shows the head loss of the horn and a specially designed angle globe valve which does not have as great a head loss as a standard globe valve. The galvanized-piping type of installation is frequently used, and one can readily see that it introduces a very high head loss.

Improvements

The question naturally occurs: What can be done to improve the flow of water into the customer's residence? To answer this question it is necessary to review once more the flow of water from the main, step by step.

First, with regard to the corporation stop, no attempt was made to improve the flow conditions in this study. The author believes, however, that better flow characteristics can be obtained by redesign of the corporation stop and an enlargement of the waterway.

In examining the curb stop, it was noted that the waterway through this device had not been reamed after the stop was manufactured. Fragments of ragged metal and burrs were found in the waterway. One of the round-

opening curb stops was taken apart and the rough metal fragments filed away; however, no attempt was made to enlarge the waterway. This simple operation had the effect of reducing the head loss about 1 psi at a flow rate of 15 gpm, as shown by Curve B_1 in Fig. 1. It was noted that the curb stop had a hollow plug and that the device was of very poor hydraulic design. Square-opening curb stops were even worse. It is believed that marked improvement of these fittings can be accomplished through proper design and manufacture.

Comparative flow rate tests were run, using a $\frac{3}{4}$-in. globe valve and a $\frac{3}{4}$-in. gate valve. In Fig. 1, the head loss of the globe valve is shown as Curve *C*, and that of the gate valve as Curve *D*. At the 15-gpm rate a head loss of more than 3 psi can be eliminated by using a gate valve in place of a globe valve.

One of the several models of meters used was studied for possible improvement of the chamber ports. It was noted that the outlet port of the chamber overlapped the corresponding openings in the main case. About $\frac{3}{16}$ in. was filed from the chamber port to improve the waterway. When this improved chamber was tested, it produced Curve C_1 in Fig. 3, as compared with Curve *C* for the original chamber. At this point no change was noted in either the accuracy or noise of the meter. In an attempt to improve the characteristics of the meter still further, the outlet port of the chamber was filed down until there was barely sufficient metal left to prop-

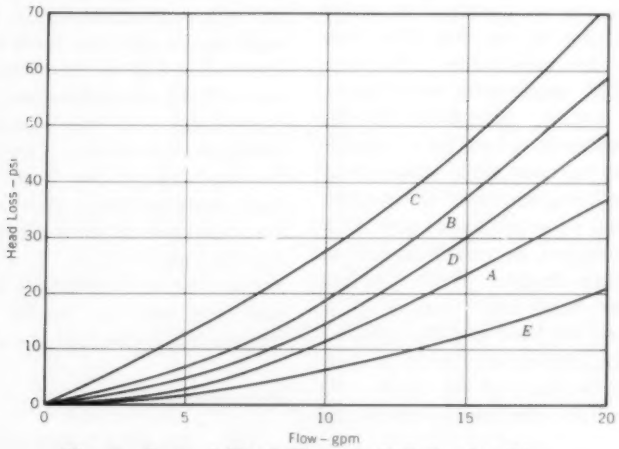


Fig. 2. Loss of Head Through Full Service Lines

Head losses through the following combinations of pipe, valves, meters, and meter horns are shown:

Curve A, *60 ft of $\frac{3}{4}$-in. copper tubing;*
Curve B, *$\frac{3}{4}$-in. full service line with $\frac{5}{8}$-in. meter;*
Curve C, *full service line with meter horn and old meter;*
Curve D, *improved full service line (with gate valve, improved corporation stop and meter chamber);*
Curve E, *1-in. service line with $\frac{3}{4}$-in. meter.*

erly seal it to the main case. This procedure reduced the head loss considerably, as shown by Curve C_2 in Fig. 3. At this point the accuracy of the meter dropped about 3 per cent at the 0.25-gpm flow rate. There was no change in accuracy at higher flow rates, nor was there any noticeable increase in the noise of meter operation.

Reviewing these factors again, it was possible to reduce head loss [1] by filing the curb stop (1 psi); [2] by using a gate valve instead of a globe valve (3 psi); and [3] by improving the chamber characteristics of the meter (2 psi). In all, a total reduction in head loss of 6 psi was achieved at the 15-gpm flow rate. Curves *B* and *D* in Fig. 2 show the effect of these improvements. Curve *D* represents improved characteristics; Curve *B*, the original flow characteristics. Under these improved conditions 15 gpm can be delivered to the consumer's premises with a head loss of about 30 psi.

The efficiency of the service may be still further increased by using a 1-in. supply line, 1-in. fittings, and a ¾-in. meter. The use of these enlarged facilities would materially improve flow conditions onto the consumer's premises and is, in the author's opinion, the correct solution to this problem. In considering this approach, however, the cost factor must be taken into account. Curve *E* of Fig. 2 shows the flow characteristics of a 1-in. service line and a ¾-in. meter. For purposes of comparison, Curve *B*, which shows the head loss characteristics of a ¾-in. line and ⅝-in. meter should be examined. Comparison of the costs involved shows the materials required for a ¾-in. service line with ⅝-in. meter cost about $75; while those used for a 1-in. service line with ¾-in. meter cost about $105. This difference of about $30 represents approximately 40 per cent of the total cost of the service line to the consumer's premises. It is only to be expected that builders will object to spending this additional amount for service lines. Although the author believes that every attempt should be made to use 1-in. service lines, he is also of the opinion that considerable improvement can be made in the flow characteristics of the fittings and meters now commonly used.

An important factor in this problem is that there are many thousands of service lines already in use which will be called on to deliver increasing demands of water. Every effort should be made to reduce the head loss in these existing service lines where such correction can be made without digging up the service pipe. The only place this can readily be done is within the consumer's premises, by corrections involving the valve ahead of the meter and the meter itself. A change from a globe valve to a gate valve and redesign of the meter will result in considerable reduction of head loss.

Recommendations

The following paragraphs are intended as a constructive criticism of the manufacturers of water works supplies and equipment. It is the author's hope that they will be accepted as they are intended—that is, as a request that attempts be made to improve present facilities to meet present requirements.

The water meter may be taken as an example: the principle of metering water in small quantities for domestic services was established about 60 years ago and has not been changed in any basic manner since that time. For many years, one of the chief articles in the philosophy of the water works industry has been interchangeability of parts, and most water works men have expressed the desire for a meter in

which replacement parts could be used without the necessity of replacing the entire meter. Such an approach undoubtedly has certain advantages; yet it appears to the author to be a striking indication of lack of progress. This is not intended as a recommendation to discard the old merely because it is old. It is, however, the author's firm conviction that progress in the design of meters and other water works facilities has been impeded by that philosophy of the water works industry which has insisted so strongly on interchangeability. In passing through a water meter the direction of flow must twice be reversed a full 180 deg. The ports and channels through which the water must flow are small and, the author believes, improperly placed. An entirely new concept of water metering is required to provide a basis for the type of meter the water works industry must have if it is to meet modern flow requirements without excessive head loss.

Another major tenet in the philosophy of the water works industry has been a demand for extremely high accuracy at low flow rates. The AWWA standard specifications for water meters (C700 series) require an accuracy of 95 per cent at a flow rate of 0.25 gpm. Some cities demand an accuracy of 97 per cent at this flow rate. The fact is, however, that meters will not maintain this high degree of accuracy when in use. Tests have shown that at low flow rates accuracy falls off as much as 20–30 per cent after the meter has passed 100,000 cu ft but that good accuracy is maintained at the higher flow rates. If, in order to develop a meter which will provide lower head loss, it is necessary to sacrifice some of this high accuracy at the low flow rates, the author believes such a sacrifice to be justified. To serve as an example, the author performed some computations upon leakage loss data for Philadelphia. If a consumer's pipe were leaking at a

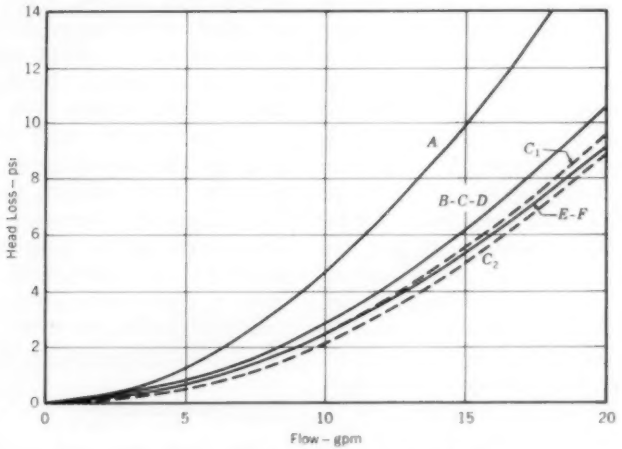


Fig. 3. Loss of Head Through Meters

The solid-line curves A–F *indicate head loss characteristics of six* ⅝*-in. meters of different manufacture. Broken-line curves* C_1 *and* C_2 *show head losses through improved versions of meter* C.

rate of 0.25 gpm, and the accuracy of the meter were to be reduced from 95 to 75 per cent (at the 0.25-gpm rate), the loss of revenue to the Philadelphia Water Department in a full year would be about $1.50. If there were 10,000 such leaks in the system, the total revenue loss for the year would be about $15,000, or 0.1 per cent of the department's annual revenue. If, on the other hand, it were necessary to increase pressures throughout the system by 10 psi (which, incidentally, cannot be done in Philadelphia because of reservoir elevation), the cost of extra power for this increased pumpage would be nearly $500,000 annually. Magnetic and sonic meters have been developed with very high accuracy at low as well as high flow rates and without moving parts in the stream flow. At present these devices are too costly to be used instead of displacement meters. The meter industry should give serious consideration to research toward the design of a meter that will render reasonably satisfactory measuring service at a considerably reduced head loss. In all probability, this research will not be performed until water works practitioners demand it.

The example of the meter has been cited merely as one indication of the kind of improvement needed. Similar study should be given to other devices such as gate valves, globe valves, and curb stops. By means of thorough research and proper design, the head loss now suffered in delivering high flow rates to consumers' premises can be materially reduced. In addition, the author believes that more rigorous quality control is needed in the manufacture of such items as valves and stopcocks.

The comments made with regard to water meters are more detailed than those for other fittings because the meter is a more complex instrument. Redesign of the meter to reduce head loss will require more extensive research and considerably more time than will be required to redesign the other fittings.

Those who must purchase supplies and equipment by competitive bidding can obtain protection against inferior products only by means of a rigid specification. Specifications should establish head loss limits and should require proper finish of manufactured articles to eliminate ragged metal and burrs in waterways. The standard specifications of the AWWA should afford protection to water works practitioners against the manufacturer who makes an inferior article.

Conclusions

It has long been the general practice of the water works industry to consider flow rates onto consumers' premises in the magnitude of 5–6 gpm. At these rates, head loss has not been an important factor. Because of the increasing number of residential water-using devices, however, flow rates are becoming more significant and head loss of paramount importance to the water works industry. It should be pointed out that some kinds of automatic washing machines require a residual pressure of 20 psi while the machine is filling in order to operate properly. Because of the large head losses suffered with normal service lines and connections, these flow rates and satisfactory residual pressures cannot be obtained. Consumers will be inconvenienced by being unable to draw water at fixtures above the ground floor when several devices are in operation at the same time. This problem poses a challenge to the water works industry, and it is up to the water works men themselves to demand the type of equipment needed to render satisfactory water service to all

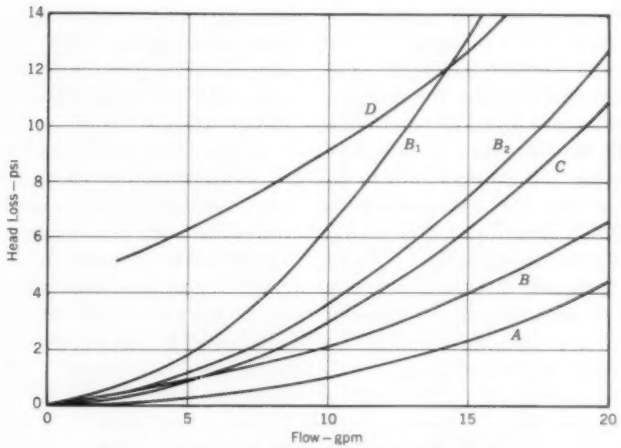


Fig. 4. Improved Head Loss Characteristics

Head losses through the following meters, valves, and connections are shown:

Curve A, *two* ⅝*-in. meter connections with* ¾*-in. spacer pipe;*
Curve B, ¾*-in. meter horn without valve;*
Curve B_1, ¾*-in. meter horn with standard galvanized-iron pipe and four elbows;*
Curve B_2, ¾*-in. meter horn with angle globe valve;*
Curve C, *new meter;*
Curve D, *old meter (unrepaired) of same model as meter* C.

consumers. Only when the water works men demand these improvements will the manufacturers produce the required equipment. It is the author's belief that the entire water works industry has been too complacent in accepting equipment and devices of standard design influenced by its desire for interchangeability of parts. Members of the water works fraternity must raise their sights and seek improved facilities if they are to render the type of service the consumer is demanding.

References

1. Thompson, Leonard N. Data Sheet for Computation of New Service Lines. Water Dept., St. Paul, Minn. (1955).
2. Buzzard, Lester, Hays Mfg. Co., Erie, Pa. Private communication.

Discussion

James G. Carns Jr.

Meter Engr., American Water Works Service Co., Philadelphia, Pa.

The author has indeed presented a very important problem to water works operators and one which should receive serious consideration. Although not in agreement with a number of the author's conclusions, the writer does endorse the premise that the generally accepted practice of installing ¾-in. service lines for all domestic customers is no longer a good one and could result

in making many installations obsolete within a short time. When consideration is given to the fact that the investment cost of water services and meters represents an average of 15–20 per cent of the total plant investment of a water utility, it is clear that the problem is not insignificant. If the demands—either actual or potential—being placed on these facilities are as large as the author has indicated (and the writer believes they are) it seems only prudent that every effort be made to insure that the facilities will continue to have the long life which past experience has shown may be expected.

One point which might be added to the author's remarks is that many of the relatively new water-using appliances—such as washing machines, dishwashers, and garbage-disposal units—are automatic and are therefore bound to influence adversely the diversity of use that has been noted in the past. It is much more reasonable, for example, to expect simultaneous use of water for dishwashing and laundering with automatic equipment than when these are done manually. Indeed, the increased leisure time resulting from the use of such automatic facilities is the primary reason for their existence.

It is difficult, however, to understand the reasoning leading to the conclusion that there is basic fault to be found in either the design or quality control of water works equipment, as the author suggests. Improvements could, of course, be made in both these areas, if water works operators were willing to accept the additional costs involved. There are, in fact, a number of "premium" items manufactured today which, because of higher cost, do not sell in the quantity which would normally be expected. This lack of demand does not seem to be the result of a lack of knowledge or foresight on the part of the purchaser. The writer is more inclined to believe (on the basis of the author's own data) that the benefits gained through such improvements not only would fail to solve the basic problem, but would result in economic waste. It has been stated that water pressure in the street mains of many cities is 30–40 psi and that the friction loss through 60 ft of ¾-in. Type K copper tubing *alone* is 24 psi at a flow of 1 gpm. It is obvious that if all the other components comprising the service and meter installation were available with absolutely no head loss, the pressure at the cellar wall of a residence would be only 6–16 psi during periods of maximum use. Such low pressures would not be sufficient to provide for the difference in elevation to the water outlets being used as well as friction losses in house piping and fixtures. The answer then, as the author indicates, is a larger service for such operating conditions—and the cost factor does not come into consideration at all. A 1-in. service line must be installed or the peak demands will not be satisfied. There is no alternative.

The writer does not, however, believe it necessary or prudent to pay a premium for improved design or quality in other components which go to make up the complete service and meter installation. Although the friction loss for 1-in. copper tubing is not given by the author, data available to the writer show the loss through 60 ft of this tubing to be 4.2 psi at a 15-gpm rate, as compared with the figure of 24 psi given by the author for ¾-in. tubing. If, therefore, a 1-in. service were installed instead of a ¾-in. line for the conditions noted, overall

service and meter friction loss would be about 20 psi, including the loss through a $\frac{5}{8}$-in. meter. Thus, the writer believes that if a 1-in. service were installed it would be unnecessary to increase meter size above $\frac{5}{8}$ in. or to pay a premium for other improved components in the large majority of installations.

The question has been raised whether extreme accuracy of meters on low flows should be required. Argument on this subject would be a good deal like a controversy involving religion: one either believes, or he does not. The writer, however, would like to point out a few factors which should be considered. A most exacting study on the subject of water used by domestic customers involved the determination of the actual quantities used at various rates of flow in 160 one- and two-family homes in four widely separated communities. Results showed that 16.47 per cent of all water used was at rates of 0.25 gpm or less. If meters 20 per cent less accurate at the 0.25-gpm rate were installed, the loss in registration would be one-fifth of this figure, or an overall loss of more than 3 per cent. This, however, would not be applied only to those accounts where leaks are present, but to all accounts in a system. The writer has conducted numerous comparative tests of meters in service—both new and repaired—and results have shown that a large loss occurs when meters are not sensitive to low flows. In one instance, with two new meters installed in tandem, one has registered 739,800 gal and the other only 626,900 gal over a period of 6 years—a difference of over 15 per cent. A large number of tests on similar installations show the difference may average around 5 per cent. What, then, may be the difference or loss in registration and revenue if meters are installed without reasonably proper repair? Obviously, a decision on the degree to which meter accuracy at low flows should be carried must be based on economics, and the cost of increased maintenance must be weighed against potential loss of revenue. The latter, of course, is a variable, depending mainly on rates for water service. If, however, the basic concept of metering is to be fulfilled—that is, to divide the cost of water service equitably among all customers on the basis of use—all meters in service should be maintained on the same level of efficiency as far as is reasonably possible; and this requires adequate maintenance procedures, including provision for meter accuracy at low flows.

Palatability is in Good Taste

. . . and many water supplies to be made palatable, should receive adequate dosages of AQUA NUCHAR activated carbon. The amount of AQUA NUCHAR required varies with seasonal changes in algae and trade-waste concentrations, and with different methods of water purification. Frequent Threshold Odor Tests will indicate the amount of AQUA NUCHAR required to produce palatable water.

Our technical staff will gladly, without obligation, give your plant a complete odor survey and recommend how and where AQUA NUCHAR can best be used to produce palatable water.

GOOD CARBON · GOOD WATER · GOOD WILL

New York Central Building
230 Park Ave., New York 17, N. Y.
Phila. Nat'l Bank Bldg.
Broad & Chestnut Sts., Phila. 7, Pa.

industrial CHEMICAL SALES
division west virginia pulp and paper company

Pure Oil Building
35 E. Wacker Drive, Chicago 1, Ill.
2775 S. Moreland Boulevard
Cleveland 20, Ohio

Modern register installed 1955
Original meter purchased 1913
Oil-enclosed type gear train installed 1925
New, current-model measuring chamber assembly installed 1955
Disk piston rebuilt 1925, 1942

How NEW is this Meter?

It was built in 1913 . . . but it's almost as new as 1956. Over the years, working parts have been replaced. Its performance matches every standard of modern metering practice.

The parts used to repair this meter at its last overhaul are identical to those used in the latest Trident meters. They embody every thoroughly tested advancement known to the science of metering.

Designing modern parts to fit "old" meters has been a rigid Neptune policy for over 50 years. It is just one of the extra advantages that make Tridents a better buy . . . both for today and for the years to come.

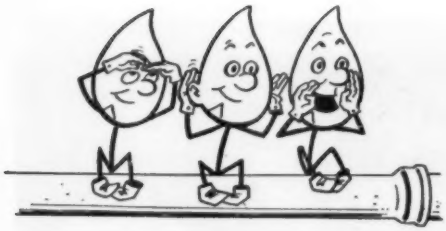
NEPTUNE METER COMPANY
19 West 50th Street, New York 20, N. Y.

NEPTUNE METERS, LTD.
1430 Lakeshore Road, Toronto 14, Ontario

Branch Offices in Principal American and Canadian Cities.

274

neptune



Percolation and Runoff

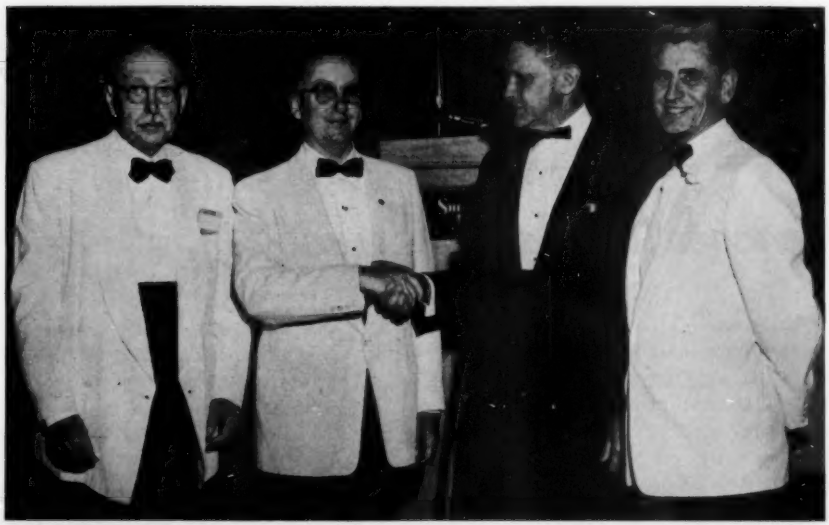
Jubilation—Diamond Jubilation—was the keynote of AWWA's 75th Anniversary meeting in St. Louis last May 6–10, an aura of past achievement permeating every part of a program built upon the problems and practices of today. With a second straight 2,500-plus registration, with still another record exhibit, with more and fuller technical sessions and committee meetings, with a social program playing to such capacity crowds as at the Anniversary Banquet (see photo, p. 38), there was an aura, too, of bigness—a realization that AWWA is getting "big," not only in its 11,000 membership, not only in its 75-year record of service, but in the eyes of a public that is at last beginning to appreciate the field which it serves. Thus, what once was pretty much of a family party has, over the years, become an affair of national and even international importance. For all of its ceremony and significance, however, the Diamond Jubilee celebration managed to preserve the best features of a family affair. Between sessions, along the promenade and midway of the exhibit hall, at the various dinners and dances, out at the ball park, or behind one of the famous St. Louis brews in a hospitality room, the "old home week" elements of AWWA meetings were just as evident as ever. And it was this happy combination of consequence and conviviality that made the "jubilation" real.

On hand to jubilate were 2,536 members and guests, only 50 below last year's Chi high, and almost 500 above the total at any other meeting. And on hand for their jubilation was a program of 16 technical sessions, 182 boothsful of the products of 100 manufacturer-members, a dozen different inspection trips, and a full week of committee meetings and free-for-all bull sessions. All this kept all the men busy at Kiel Auditorium every day, but at night they joined the ladies for the party part of the birthday celebration.

Beginning Sunday evening with a Birthday Buffet and get-together, the social schedule turned to tradition on Monday night to honor AWWA's 1956 Men of the Year: Percy Black, Henry Cronin, Tom Skinker, and Victor Weir, who became Honorary Members; Bill Orchard, who received the Harry E. Jordan Achievement Award; Fred Gordon, Diven Medalist; H. S. Swanson, H. J. Chapton, C. L. King, and E. D. Nelson, who combined to take the Goodell Prize back to Los Angeles; Leslie Paul, Abel Wolman, Arnold Cherry, and Finley Laverty, winners of the Distribution, Management, Purification, and Resources Di-

(Continued on page 36 P&R)

(Continued from page 35 P&R)



Above: The Polished Brass—Treasurer Bill Brush, President Paul Weir, Past-President Frank Amsbary, Vice-President Fred Merryfield. Below: One of the Brass Bussed and Bedecked—Treasurer Bill Brush with Mrs. Edward Morgan of Honolulu, just after she hung a lei around his neck and gave him the traditional kiss.

(Continued on page 38 P&R)

New Recarbonator Principles

provide GREATER EFFICIENCY in MUCH LESS SPACE

Revolutionary new water stabilization system with control panel can be designed to meet your requirements.

Proved in actual service, this development by INFILCO engineers offers you many advantages in CO_2 generation and distribution.

Since the burner and combustion chamber are located in the top of the "downcomer," the lower portion of which is immersed in the recarbonation basin water itself, costly cooling apparatus is eliminated. There are no exposed hot gas lines.

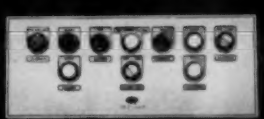
You get greater efficiency from less than 1/3 the space required by the old-style systems. Complete combustion gives clean gases in exact quantities — no need for scrubbing. Corrosive effect of gases is reduced. Proper controls make operation safe, simple and subject to visual check. Scaling from calcium carbonate and magnesium hydroxide is minimized.

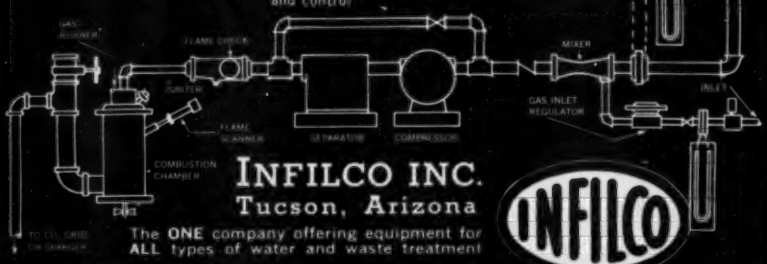
Only INFILCO engineering and equipment give you all these advantages.

Facilities are available throughout the nation to help you solve your problem. Write today for complete details.

COMPLETE COMBUSTION

Typical control panel, indicating simplicity of operation and control





INFILCO INC.
Tucson, Arizona

The **ONE** company offering equipment for **ALL** types of water and waste treatment

INFILCO

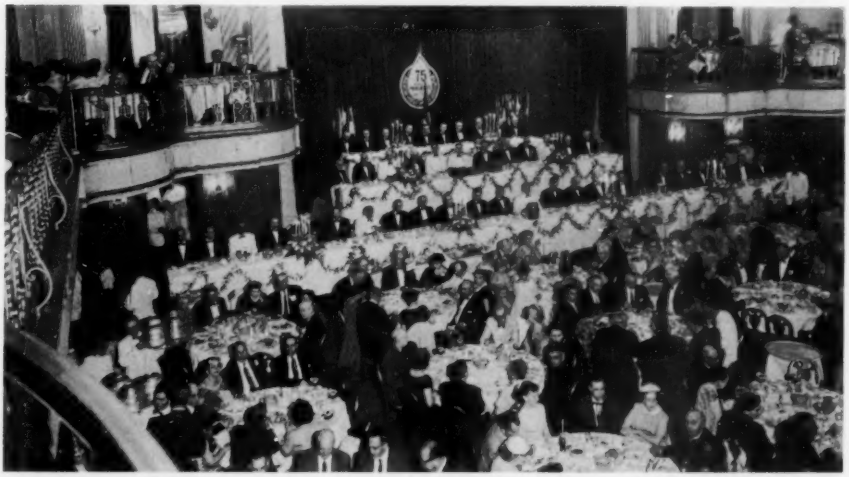
FIELD OFFICES IN PRINCIPAL CITIES IN NORTH & SOUTH AMERICA

5609

(Continued from page 36 P&R)

vision Awards; Marvin Lindorf, recipient of the Harry E. Jordan Scholarship Award, established in 1954 by the Water & Sewage Works Manufacturers Assn.; and 28 new winners of the George Warren Fuller Award. Having opened with an operetta and other selections by a group from the Washington University Fine Arts School, the evening was topped off by a reception and dance.

Tuesday night introduced something different in entertainment when an orchestra from the St. Louis Symphony and a chorus from the Municipal Opera combined to produce an evening of Rodgers and Hammerstein tunes from such favorites as *Carousel, South Pacific, Allegro, The King and I,* and *Oklahoma!* With Wednesday night off for such rugged individualism as the Cardinals-Phillies game (and it was cool that night), the sights of town, or even the attractions of East St. Louis, Thursday night's sellout Anniversary Banquet & Ball provided the high spot of the week for the 1,100 who were able to crowd into the Gold Room of the Jefferson Hotel. Getting off to a beautiful start when the officers and honored guests were bedecked with leis and hand orchids flown in from the Hawaiian Islands by Mr. & Mrs. Edward J. Morgan of the Honolulu Board of Water Supply, the program was featured by the presentation of certificates of honor to the executives of 34 Associate Member firms who have been members of the Association for 50 years or more (see pp. 76, 78). Speaking for these charter members of the Veeps,* Colonel Rockwell, representing the National Meter Division of Rockwell Manufacturing Co., member since 1882, congratulated the Association on its cooperation with the manufacturers' group in his acceptance. With the awarding of the Hill Cup to the Southwest Section, the Henshaw Cup to the Cuban Section, and the Old



Anniversary Banquet—Gold Room, Jefferson Hotel

* Veep for V.P. for Venerable Peddler, of course.

(Continued on page 42 P&R)

How to Locate Water Leaks

WITH SIMPLEX PITOT EQUIPMENT

WHY not decrease your load and stop pumping to waste? Locate the hidden leaks which waste thousands of gallons per day per mile of main . . . far more than usually guess-timated!

Locating these leaks with Simplex Pitot Equipment costs only a tiny fraction of the value of the water being wasted. You get accurate flow records with minimum effort . . . valuable data that will help you to reduce "unaccounted-for water" to a minimum.

PITOT ROD

Simple, rugged and lightweight. Easily installed on any pipe or main. Special clamp holds tube firmly in position against water pressure.

Low coefficient gives high differential pressure for greatest accuracy.

MANOMETER

Quickly connects to a Simplex Pitot Rod with flexible tubing. You then have a simple, sensitive and inexpensive instrument for indicating rate of flow.

Can be used for wide flow ranges . . . low or high.

PITOT RECORDER

Connects easily to Pitot Rod. Eight-inch chart records flow data. Simple and rugged construction . . . no delicate mechanisms . . . yet sensitive and accurate.

Sturdy carrying case. Leveling feet. Reliable 7-day clock movement for chart. Accurately calibrated.

Get the Facts!

Free 20-page Technical Bulletin 1300. Full instructions for use and care of Pitot equipment. Seven pages of helpful formulae, tables, curves. Write to Simplex Valve & Meter Co., Dept. JA-6, 7 E. Orange St., Lancaster, Pa.

SIMPLEX®

VALVE AND METER COMPANY

1956 CONFERENCE STATISTICS

(See story on p. 35 P&R)

St. Louis Registration by Days

Day	Men	Ladies	Total
Sunday, May 6	976	287	1,263
Monday, May 7	792	212	1,004
Tuesday, May 8	143	11	154
Wednesday, May 9	80	–	80
Thursday, May 10	35	–	35
TOTALS	2,026	510	2,536

Geographic Distribution of Registrants

UNITED STATES & TERRITORIES

Alabama	39	Maryland	24	South Dakota	13
Arizona	12	Massachusetts	30	Tennessee	46
Arkansas	33	Michigan	64	Texas	83
California	115	Minnesota	34	Utah	6
Colorado	30	Mississippi	16	Virginia	29
Connecticut	25	Missouri	268	Washington	18
Delaware	4	Montana	9	West Virginia	16
Dist. Columbia	19	Nebraska	31	Wisconsin	40
Florida	31	New Hampshire	3	Wyoming	1
Georgia	58	New Jersey	106		
Hawaii	2	New Mexico	2	**CANADA**	
Illinois	308	New York	211	Ontario	54
Indiana	101	North Carolina	23	Quebec	1
Iowa	75	North Dakota	5		
Kansas	59	Ohio	140	**FOREIGN**	
Kentucky	33	Oklahoma	31	Asia	5
Louisiana	28	Oregon	6	Europe	2
Maine	4	Pennsylvania	205	South America	4
		Puerto Rico	1		
		Rhode Island	13	**TOTAL**	2,536
		South Carolina	19		

Comparative Registration Totals—1947–1956

Year	Place	Men	Ladies	Total
1956	St. Louis	2,026	510	2,536
1955	Chicago	2,075	512	2,587
1954	Seattle	1,536	527	2,063
1953	Grand Rapids	1,532	365	1,897
1952	Kansas City	1,600	386	1,986
1951	Miami	1,415	491	1,906
1950	Philadelphia	1,678	329	2,007
1949	Chicago	1,593	374	1,967
1948	Atlantic City	1,348	356	1,704
1947	San Francisco	1,115	431	1,546

Win, Place & Show in Section Awards

Henshaw Cup		Hill Cup		Old Oaken Bucket	
Cuban	**72.2%**	**Southwest**	**28.67**	**California**	**1,266**
Montana	68.4%	Indiana	24.47	Southwest	994
Pacific Northwest	55.0%	California	19.98	New York	822

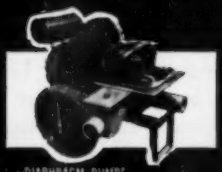
THE NATION'S No. 1 SOURCE

for dependable pipe line equipment

Like hundreds of Pollard customers, you'll find it mighty pleasant and convenient to order pipe line equipment from Pollard.

Here, under one roof and listed in one comprehensive catalog, are all the time and money saving products you need on the job. Each is guaranteed for dependability, economy. Each is backed by Pollard service.

MANHOLE CUSHION


DIAPHRAGM PUMPS

JOINT RUNNERS

PIPE CUTTERS

MAKE POLLARD YOUR SOURCE FOR PIPE LINE EQUIPMENT. ORDER FROM POLLARD CATALOG 26.

M-SCOPE PIPE FINDER

CALKING TOOLS

MELTING FURNACE

PIPE LINE EQUIPMENT

JOSEPH G. POLLARD CO., INC.

PIPE LINE EQUIPMENT

PIPE LINE EQUIPMENT

Place your next order with POLLARD

If it's from POLLARD . . . It's the Best in Pipe Line Equipment

NEW HYDE PARK • NEW YORK

Branch Offices: 1064 Peoples Gas Building, Chicago, Illinois
333 Candler Building, Atlanta, Georgia

(Continued from page 38 P&R)

Oaken Bucket to the California Section, President Amsbary then gave up the gavel to Paul Weir, whose inaugural speech was featured by a toast to water in water.

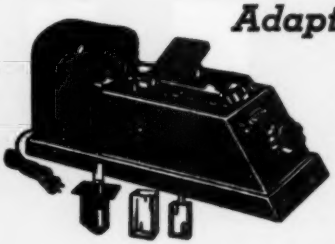
On the program of the Banquet as well as in, behind, over, and around every other part of the program was Victor Weir, chairman of the Convention Management Committee, whose coordination of the work of more than a hundred members of the local section and nearby Illinois members resulted in the smooth operation of the affair as a whole. Vic, of course, claimed that he had merely reaped the credit for the work of his lieutenants such as Vance Lischer, Tom Skinker, Gene Butler, and Herb Hartung, not to forget Carl Buettner, who, in addition to chairmanning the Banquet Committee, produced the Diamond Jubilee seal that decorated the backdrop of the head table (see p. 38). As for the ladies, their part of the jubilation was credited to the other half of the coordinating Weirs—Mrs. W. V., that is, who, with Mrs. Tom Skinker and the Missuses Butler, Casteel, Dean, Dolson, Hartung, Lischer, and Wenger, kept the ladies busier even than the men with tours and teas and luncheons and fashion shows through the week.

After a week such as St. Louis, it isn't easy to imagine how any future meeting can measure up—at least until 1981—but "Wait till next year," the New Jersey Section says. And Atlantic City does have a way of measuring up and over the highest of standards. Mark your calendar for May 12–17 now! It will be a double natural —AWWA's 77th Annual Conference.

(Continued on page 44 P&R)

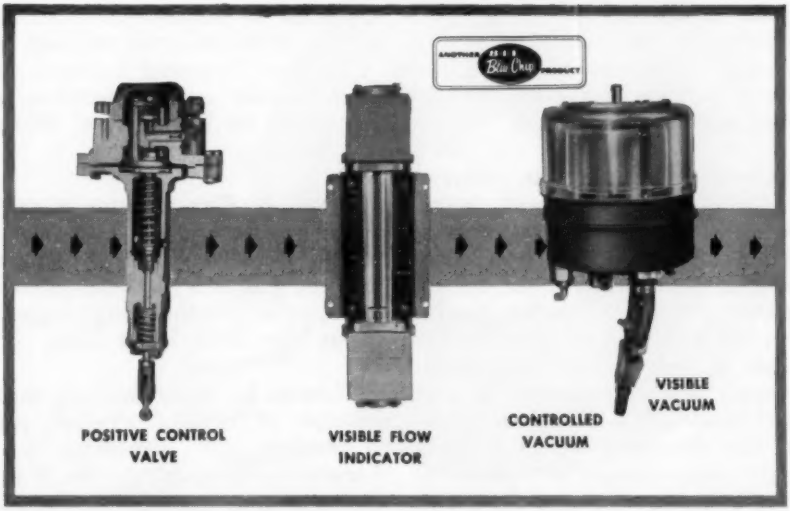
KLETT SUMMERSON
ELECTRIC PHOTOMETER

Adaptable for Use in Water Analysis



Can be used for any determination in which color or turbidity can be developed in proportion to substance to be determined

KLETT MANUFACTURING CO.
179 EAST 87th STREET · NEW YORK, N. Y.



IN CHLORINE GAS FEEDERS . . .

LOOK FOR KNOW-HOW

Here's proof of good chlorine feeder design! The gas flow path shown in this Builders-Providence flowgram is the shortest offered by any manufacturer of chlorination equipment . . . and we invite comparison! Good design means maximum dependability (to the consulting engineer) . . . ease of installation (to the contractor) . . . and easy operation, low upkeep, and low operating cost (to the operator).

Our design offers all these and more. For added safety . . . there are no springs or piloted parts in contact with chlorine, no packed valve stems to leak and destroy feeding accuracy . . . and the simplicity of the entire system means better operation with less maintenance.

These superior features did not just happen — but are drawn from the vast reservoir of B-I-F application knowledge and experience gained as the major manufacturer of flow metering, and control equipment for WATER, SEWAGE, and WASTE TREATMENT PLANTS. Many consulting engineers have profited by the valuable assistance received from B-I-F specialists. Our policy of continuing research and development has produced the most comprehensive, service-proven line available . . . and thousands of superior performance records reflect our broad design and manufacturing experience.

* * *

If you have a chlorine gas feeding problem, our engineers will gladly help you solve it. A call to GAspee 1-4302 in Providence . . . or to one of our local offices . . . will put us at your service. B-I-F Sales and Service Offices are located across the country for your convenience. Act today! Builders-Providence, Inc., 365 Harris Avenue, Providence 1, Rhode Island.

B-I-F INDUSTRIES

PROVIDENCE, RHODE ISLAND

METERS FEEDERS CONTROLS

(Continued from page 42 P&R)

John E. Olsson, of Lincoln, Neb., formerly with the engineering firm of Fulton & Cramer, has opened his own office to practice as a municipal consulting engineer.

Philadelphia Quartz Co. celebrates its 125th anniversary next month. Founded in 1831 for the manufacture of soap and candles by Joseph Elkinton, great-grandfather of the current president, Thomas W., the firm became interested in silicates during the 1850's. Silicate production constituted an increasingly important share of the company's business, and in 1905 soap making was discontinued. Philadelphia Quartz now operates a number of plants in the eastern part of the United States, with associate companies in California and Canada.

Arthur W. Consoer, chief executive partner in the consulting engineer firm of Consoer, Townsend & Assocs., has been awarded a distinguished-service citation by the University of Wisconsin, Madison.

Larry A. Kay, director of public health engineering, Manitoba Dept. of Health & Public Welfare, Winnipeg, has been granted a year's leave to serve as an adviser in public health engineering at New Delhi, India.

Thomas L. Ward has been named manager of the Alco Products plant at Dunkirk, N.Y., succeeding W. L. Larson, who has resigned. Mr. Ward's former post of manager of manufacturing services has been taken by L. W. Eger.

(Continued on page 48 P&R)

AA QUALITY

For Public Water Fluoridation

Sodium Silicofluoride—98%

(Dense Powder)

Sodium Fluoride—98%

(Dense Powder or Granular)

Meets AWWA specifications

White or tinted blue
Minimum of dust in handling
Minimum of storage space

Available in bags and drums

The AMERICAN AGRICULTURAL CHEMICAL Co.

50 Church Street, New York 7, N. Y.

here's what "out of sight out of mind" does to a water main

"Out of sight—out of mind" can be a mighty expensive philosophy in any water distribution system. The above unretouched photograph proves this point. It shows a badly tuberculated *eight inch* main whose *inside diameter was reduced to an average of almost 4.5 inches.* Resultant higher pumping costs with reduced pressure and carrying capacity make it costly to tolerate such conditions. That is why the savings effected in reduced pumping costs frequently pay for the *low cost* of National water main cleaning.

Since there's never a charge or obligation to inspect your mains, *call National now!*

Call in National today!

NATIONAL WATER MAIN CLEANING COMPANY

50 Church Street • New York, N. Y.

ATLANTA, GA; 333 Candler Building • BERKELEY, CALIF; 905 Grayson Street • DECATUR, GA; P. O. Box 385 • BOSTON, MASS; 115 Peterboro Street • CHICAGO; 122 So. Michigan Avenue • ERIE, PA; 439 E. 6th Street • FLANDREAU, S.D; 315 N. Crescent Street • KANSAS CITY, MO; 406 Merchandise Mart and 2201 Grand Avenue • LITTLE FALLS, N.J; BOX 91 • LOS ANGELES; 5075 Santa Fe Avenue • MINNEAPOLIS, MINN; 200 Lumber Exchange Building • RICHMOND, VA; 210 E. Franklin Street • SALT LAKE CITY; 149–151 W. Second South Street • SIGNAL MOUNTAIN, TENNESSEE; 204 Slayton Street • MONTREAL, CANADA; 2032 Union Avenue • WINNIPEG, CANADA; 576 Wall Street • HAVANA, CUBA; Lawrence H. Daniels, P. O. Box 531 • SAN JUAN, PUERTO RICO; Luis F. Caratini, Apartado 2184.

6 TIMES MORE THAN WE NEED

MODERNIZED **cast iron**

RAINFALL ...still not enough!

No secret to you that water is America's No. 1 Problem... that rainfall is largely wasted, unevenly distributed or polluted.

But does the public know it?

It's important that the great mass of the American people learn the facts. We're helping there.

Month after month our national advertising stresses the need for long range planning of water facilities; public support for realistic water rates; necessary water works financing; conservation by homeowner and industry.

Our aim... like yours... is to alert the public to the growing seriousness of water shortages... enlist their cooperation so that we—and our children—will be assured of a plentiful supply of water for all our needs.

CAST IRON PIPE

proved by Performance

Over a hundred years ago cast iron pipe mains were laid by more than 70 American utilities. They're still working efficiently.

Here's proof of cast iron pipe's dependability and longevity... its savings in maintenance costs and tax dollars.

Today's modernized cast iron pipe, centrifugally cast for greater strength and uniformity, is even more durable. Where needed, it can be cement-lined for sustained carrying capacity through generations of hard use.

When you specify pipe for your water system, remember: no other pipe can match cast iron's *proved* record of performance. It serves for centuries.

Cast Iron Pipe Research Association, Thos. F. Wolfe, Managing Director, 122 So. Michigan Ave., Chicago 3, Illinois.

This rugged old cast iron water main, laid 125 years ago, is serving and saving tax dollars for the citizens of Detroit, Michigan.

CAST IRON

The Q-Check stenciled on pipe is the Registered Service Mark of the Cast Iron Pipe Research Association.

pipe FOR MODERN WATER WORKS

(Continued from page 44 P&R)

B–I–F Industries, Providence, R.I., has appointed six district engineers who can be called on for aid in solving problems involving meters, feeders, and controls. Heading the new service is M. E. Rogers, project sales manager of Builders-Providence. The six district engineers, and their home cities, are: C. K. Perkins, New York; D. A. Wood, Washington, D.C.; B. E. Hamlett, Pittsburgh; G. E. Riepe, Chicago; E. F. Morey Jr., Dallas; and L. H. Chamberlain, San Francisco.

Research assistantships and post-doctoral fellowships for fundamental research in water chemistry are available in June and September at the University of Florida, Gainesville. Stipends range from $2,000 to $5,000. The wide-range research program of the newly established Div. of Water Research is under the general direction of Dr. A. P. Black, head of the Dept. of Chemistry, and Arthur M. Buswell, recently retired chief of the Illinois State Water Survey. Some of the projects are AWWA sponsored, with an AWWA advisory committee participating in their direction.

New president of the National Society of Professional Engineers is Robert J. Rinehart, division superintendent, Arkansas Power & Light Co., Pine Bluff, Ark. Mr. Rinehart officially takes over Jul. 1, succeeding Allison C. Neff, vice-president, Armco Drainage & Metal Products, Middletown, Ohio.

(Continued on page 76 P&R)

BELL JOINT LEAK CLAMPS
GASKET SEALER COMPOUND
C-I-60 CAST IRON BOLTS

Carson glands and bolts made of corrosion-resistant C-I-60 cast iron—last as long as cast iron pipe. Glands accommodate variations in pipe dimensions, insure uniform compression of rubber gasket.

Write for information

H. Y. CARSON COMPANY
1221 Pinson St. Birmingham, Ala.

AMONG WATER WORKS MEN

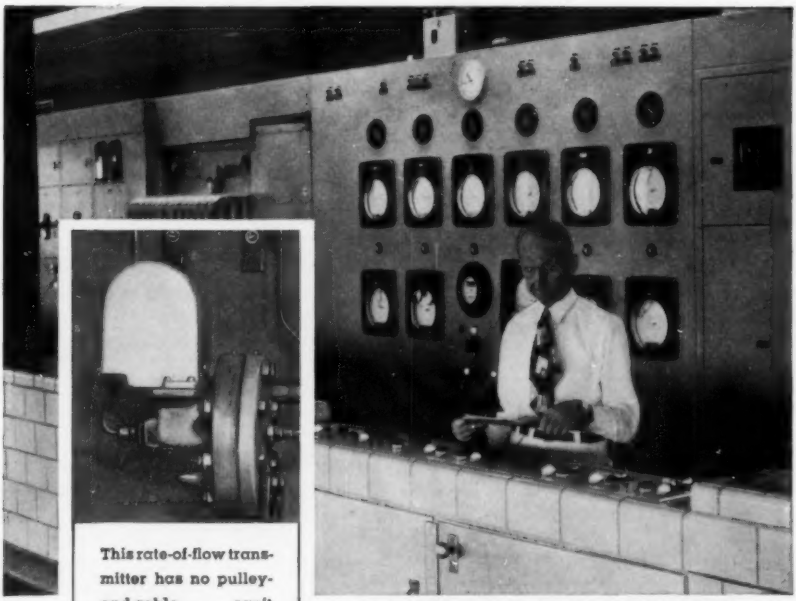
THE HEAVY-DUTY ELLIS PIPE CUTTER IS *BEST*

FOR CUTTING LARGE SIZES OF PIPE

No. 01 Cuts Pipe 4" to 8"
No. 1 Cuts Pipe 4" to 12"

Write for circular and price list No. 39J, on our complete line of pipe cutting tools.

ELLIS & FORD MFG. CO.
2425 Goodrich Ave. Ferndale, Michigan
Phone Lincoln 7-3600



This rate-of-flow transmitter has no pulley-and-cable . . . can't be damaged by over-ranging . . . uses no mercury.

At the St. Louis County Water Company's new $1,500,000 filter plant, Hine, Mo., d/p Cell Flow Transmitters tap differential pressure from venturi tubes in effluent lines of 6 filter beds . . . transmit flow measurement to M/40 Controllers shown on panel above. Controllers hold filtration rates at pre-set control points.

Smoothest-working "TEAM" you can get to control filter rates

Here's an unbeatable team for filter rate control . . . a Foxboro d/p Cell* Transmitter . . . an M/40 Controller . . . and a butterfly valve. It costs less to install and less to maintain!

The d/p Cell Transmitter has no pulley-and-cable . . . no mercury. It detects flow pressure differential across its tough metal diaphragm . . . is unaffected by backwash and sand. The Controller maintains flow at exact pre-set flow rates . . . keeps filtration in perfect balance. The rubber-lined valve provides both flow control and tight shut-off.

Write for complete information.

*Trademark

THE FOXBORO COMPANY, 166 NORFOLK ST., FOXBORO, MASS., U.S.A.

FOXBORO
REG. U.S. PAT. OFF.

FLOW CONTROL INSTRUMENTATION

FACTORIES IN THE UNITED STATES, CANADA, AND ENGLAND

JUST LIKE MOTHER USED TO MAKE

Mom's home-made bread was mighty good . . . but so is today's store bread (and probably better for you and much cheaper, too). Ace works the same way . . . highly trained water main cleaning crews using the latest patented, exclusive equipment mean much lower cost plus maximum pipe efficiency for you. Easier, faster, more efficient results . . . and results count. And you can count on Ace for water mains cleaned . . . with up to 95% of efficiency restored (at surprisingly low cost). Investigate now.

A CALL IS ALL...

Call collect, Chestnut 1–2891, Kansas City, Missouri. More facts, free estimates and surveys are yours for the asking. No obligation.

Ace PIPE CLEANING, INC.

General Offices
3513 East 18th Street
Kansas City, Missouri

Service Lines

Cutters for asbestos-cement pipe up to 20 in. in nominal diameter are described in a folder published by Pilot Mfg. Co. The light weight of the cutters is said to facilitate manual operation. Copies of the folder may be obtained from the company's main office and factory, at 3970 Pacific Coast Hwy., Torrance, Calif.

Diaphragm valves providing straight-through flow, with no dam to trap suspended matter, are described in a 4-page brochure (Bul. 101) obtainable from Stockdale Engineering Co., Dept. 119, Box 144, Haddonfield, N.J. The "Wynn" valves, said to provide two-way leakproof control of slurries and most hard-to-handle fluids, are offered in a wide range of materials, in sizes from ½ to 14 in., for pressures up to 250 psi (according to size).

Nut and bolt quality differences are discussed in an 8-page booklet (No. 717-31689-DE590) offered by Caterpillar Tractor Co., Peoria, Ill.

Analytical and diagnostic procedures for use with the "MF" Millipore Filter field monitoring kit are outlined in a 4-page folder (No. T-10) issued by Millipore Filter Corp., Watertown 72, Mass.

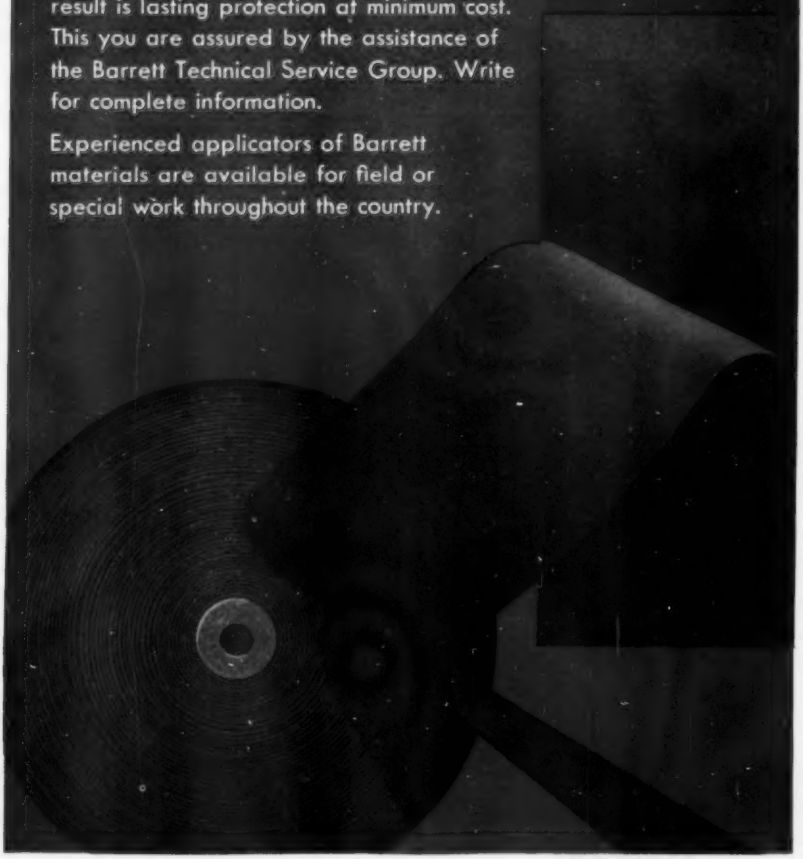
Chlorine-activated silica is produced and applied continuously by the "WT Silactor" unit (Series A-637), described in an 8-page catalog released by Wallace & Tiernan Inc. The unit is said to be capable of delivering a range of 8–160 gpd of chlorine-activated silica sol. The catalog (No. 60.110) is available from the company at 25 Main St., Belleville 9, N.J.

(*Continued on page 52 P&R*)

ALL-AROUND PROTECTION

You get all-around pipe protection with Barrett Pipeline Felt. This strong asbestos felt thoroughly impregnated with high-grade coal tar saturants is a tough, durable flexible wrapper that forms a perfect bond with Barrett Enamel. The result is lasting protection at minimum cost. This you are assured by the assistance of the Barrett Technical Service Group. Write for complete information.

Experienced applicators of Barrett materials are available for field or special work throughout the country.



Barrett®

PROTECTIVE COATINGS

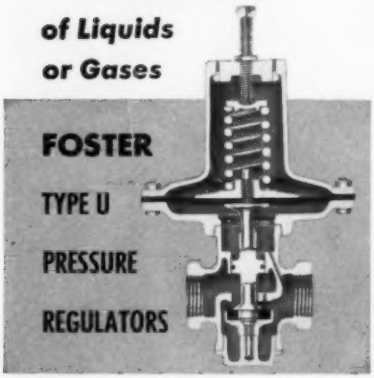
BARRETT DIVISION, Allied Chemical & Dye Corporation, 40 Rector St., N. Y. 6, N. Y. In Canada: The Barrett Company, Ltd., 5551 St. Hubert Street, Montreal, Que.

OVER 100 YEARS OF EXPERIENCE

Allied Chemical

FOR AUTOMATIC CONTROL

of Liquids or Gases



● Foster Type U Pressure Regulators are rugged. They are precision and quality built, insuring years of dependable trouble-free service for Water and other Public Works Departments. The balanced type of design allows for variations in the inlet pressure and provides greater sensitivity to the valve action, assuring accurately controlled pressure from zero to maximum flow.

Foster Type U Valves are used principally on water supply systems, commercial and apartment buildings, and many industrial uses such as bottle washing machines, air service supplies and air and fuel supply lines. Available entirely self-contained; piston operated, diaphragm actuated, or internally pilot controlled. Sizes ½" to 8" Write for Bulletin U-101.

FOSTER ENGINEERING COMPANY

835 LEHIGH AVENUE UNION, N. J.

AUTOMATIC VALVES • CONTROL VALVES
SAFETY VALVES • FLOW TUBES

(*Continued from page 50 P&R*)

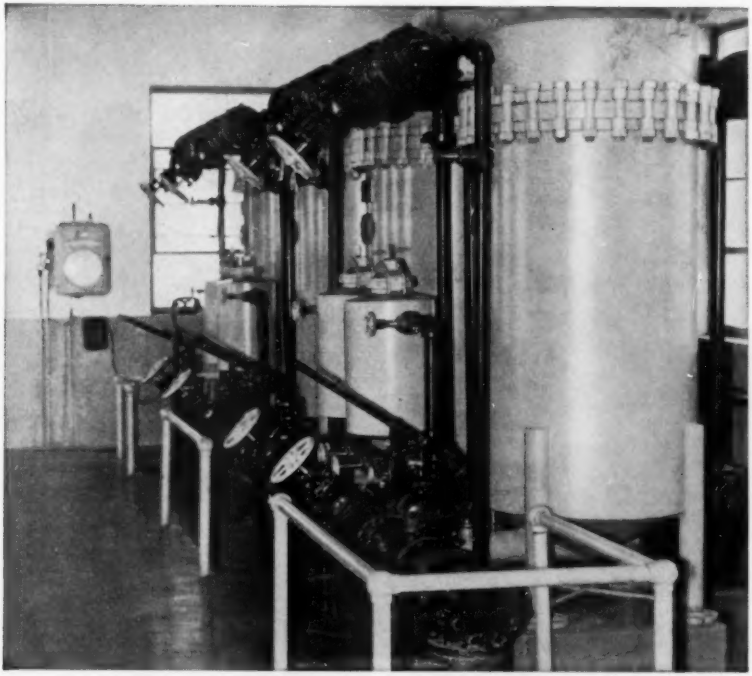
Kennedy valves, hydrants, indicator posts, and accessories are illustrated and described in a handsome 175-page, hard-covered catalog (No. 78) issued by Kennedy Valve Mfg. Co., Elmira, N.Y. Tables of dimensions, weights, and other relevant data are included.

Paints and coatings for steel tanks, standpipes, and reservoirs are discussed in a 4-page bulletin (No. 593) available from Inertol Co., 480–490 Frelinghuysen Ave., Newark 5, N.J.

Sludge removal by means of a mechanism called the "Unitube Tow-Bro," a tapered rectangular tube with orifices and sloping face, is described in an 8-page brochure issued by Chain Belt Co. The unit is said to be adaptable to both round and rectangular tanks, and to provide a clearer effluent than conventional header-and-nozzle designs. The bulletin (No. 315-81), which describes a number of plant scale installations, is available from the company, Dept. PR, Milwaukee 1, Wis.

Electric plants of 5–250-kw capacity, powered by internal combustion engines, are described in an 8-page bulletin (No. 955) issued by International Fermont Machinery Co. The booklet, which includes a compilation of selection factors for an emergency standby electric plant and typical plant specifications, is available from the company at Ramapo, N.Y.

A chlorine gas feeder of high capacity, the "Chlorinizer" (Model HCVS), is described in a 4-page bulletin, No. 840-J8A, issued by Builders-Providence, a division of B-I-F Industries, Inc. The model described—a manually controlled unit—is said to be designed primarily for rates up to 8,000 lb per 24-hr maximum with a standard meter range of 1 to 10, and to be readily adaptable to automatic and semiautomatic control. Copies of the bulletin are available from the company at 345 Harris Ave., Providence 1, R.I.



PROPORTIONEERS INC. DIATOMITE FILTERS
at Tupper Lake, N. Y., which use . . .

ALOXITE® tubes for most efficient service

Water supply for the town of Tupper Lake, N. Y., is filtered by the diatomite filters shown above. Manufactured by Proportioneers Inc. of Providence, R. I., they use ALOXITE® aluminum oxide porous tubes as the support septa.

These filters have demonstrated that ALOXITE tube septa are highly economical, and give consistently satisfactory performance. The reasons for their superiority in diatomite filtering stem from many inherent advantages. For example, a high percentage of their total area is pore area. Pre-coat builds up evenly on their uniform structure. Backwash is effective and accomplished with a high degree of uniformity. ALOXITE septa alone will even give partially effective emergency filtration. And they resist acids, which permits cleaning of units clogged by iron and other materials.

Send for free 56 page booklet.

CARBORUNDUM
Registered Trade Mark
Dept. 066, Refractories Division, Perth Amboy, N. J.

TIGHT IN THE JOINTS?
YOU BET!

Getting tight joints is simple—USE STEEL PIPE. Steel water pipe *assures* bottle-tight joints for the life of the line. When you have steel-tight joints, there is no need to over-design water pipe lines to take care of costly needless water waste. Tight joints cost less to begin with—and actually save you money through the years. It's another good reason why you're so smart to specify steel pipe.

"WHEREVER WATER FLOWS—STEEL PIPES IT BEST"

STEEL PLATE FABRICATORS ASSOCIATION

79 W. MONROE ST., CHICAGO 3, ILL.

STEEL PLATE FABRICATORS ASSOCIATION FOUNDED 1934

Professional Services

ALBRIGHT & FRIEL, INC.

Consulting Engineers

Water, Sewage, Industrial Wastes and Incineration Problems
City Planning, Highways, Bridges and Airports
Dams, Flood Control, Industrial Buildings
Investigations, Reports, Appraisals and Rates
Laboratory For Chemical & Bacteriological Analyses
Complete Service on Design and Supervision of Construction

Three Penn Center Plaza Philadelphia 2, Pa.

ALVORD, BURDICK & HOWSON

Engineers

Water Works, Water Purification, Flood Relief, Sewage Disposal
Drainage, Appraisals, Power Generation

20 North Wacker Drive Chicago 6

AYRES, LEWIS, NORRIS & MAY

Consulting Engineers

LOUIS E. AYRES ROBERT NORRIS
GEORGE E. LEWIS DONALD C. MAY
STUART B. MAYNARD HOMER J. HAYWARD

Waterworks, Sewerage, Electric Power

500 Wolverine Building, Ann Arbor, Michigan

A. S. BEHRMAN

Chemical Consultant

Water Treatment
Ion Exchange Processes and Materials
Patents

9 S. Clinton St. Chicago 6, Ill.

BLACK & VEATCH

Consulting Engineers

4706 Broadway, Kansas City 2, Mo.

Water Supply Purification and Distribution; Electric Lighting and Power Generation, Transmission and Distribution; Sewerage and Sewage Disposal; Valuations, Special Investigations and Reports

BLACK AND ASSOCIATES, INC.
BLACK LABORATORIES, INC.

Engineers and Chemists

Water, Sewerage, Hydrology, Waste Treatment
Complete Laboratory Services

700 S. E. 3rd St. Gainesville, Fla.

BOGERT and CHILDS

Consulting Engineers

CLINTON L. BOGERT FRED S. CHILDS
IVAN L. BOGERT DONALD M. DITMARS
ROBERT A. LINCOLN CHARLES A. MANGANARO
WILLIAM MARTIN

Water & Sewage Works — Refuse Disposal
Drainage — Flood Control
Highways and Bridges — Airfields

145 East 32nd Street, New York 16, N. Y.

Bowe, Albertson & Associates

Engineers

Water and Sewage Works
Industrial Wastes—Refuse Disposal—Municipal Projects
Industrial Buildings—Reports
Plans—Specifications
Supervision of Construction and Operation—Valuations
Laboratory Service

75 West Street New York 6, N.Y.

BROWN AND CALDWELL

Civil and Chemical Engineers

Water—Sewage—Industrial Waste
Consultation—Design—Operation
Chemical and Bacteriological Laboratories

66 Mint Street San Francisco 3

BUCK, SEIFERT AND JOST

Consulting Engineers

WATER SUPPLY—SEWAGE DISPOSAL—HYDRAULIC DEVELOPMENTS

Reports, Investigations, Valuations, Rates, Design, Construction, Operation, Management, Chemical and Biological Laboratories

112 E. 19th St., New York 3, N. Y.

Professional Services

BURGESS & NIPLE

Consulting Engineers

(Established 1908)

Water Supply, treatment and distribution
Sewage and industrial wastes disposal
Investigations, reports, appraisals, rates
Laboratory Municipal engineering
Supervision

2015 W. Fifth Ave. Columbus 12, Ohio

CAUSEY AND WEEKS

ENGINEERS

Designers • *Consultants*

Water Supply and Purification
Sewerage and Sewage Treatment
Investigations and Reports
Supervision of Construction

Streets and Highways

6165 E. Sewells Point Road, Norfolk 13, Va.

BURNS & McDONNELL

Engineers—Architects—Consultants

Kansas City, Mo. **Phone**
P.O. Box 7088 **DElmar 3-4375**

THE CHESTER ENGINEERS

Water Supply and Purification
Sewage and Industrial Waste Treatment
Power Plants—Incineration—Gas Systems
Valuations—Rates—Management
Laboratory—City Planning

210 E. Park Way
Pittsburgh 12, Penna.

JAMES M. CAIRD

Established 1898

C. E. Clifton, H. A. Bennett

Chemist and Bacteriologist

WATER ANALYSIS
TESTS OF FILTER PLANTS

Cannon Bldg. **Troy, N. Y.**

CHAS. W. COLE & SON

Engineers—Architects

Sewerage, Water Supply, Bridges,
Highways, Toll Roads, Industrial, Municipal
and Commercial Buildings

220 W. LaSalle Ave. South Bend, Indiana
Central 4-0127

CAMP, DRESSER & McKEE

Consulting Engineers

Water Works, Water Treatment,
Sewerage and Wastes Disposal,
Flood Control

Investigations, Reports, Design
Supervision, Research, Development

6 Beacon St. **Boston 8, Mass.**

CONSOER, TOWNSEND & ASSOCIATES

Water Supply—Sewerage
Flood Control & Drainage—Bridges
Ornamental Street Lighting—Paving
Light & Power Plants—Appraisals

351 E. Ohio St. **Chicago 11**

CAPITOL ENGINEERING CORP.

Consulting Engineers

Water Works, Sewage Disposal, Airports,
Dams and Bridges, Roads and Streets,
Planning, Design and Surveys.

Dillsburg, Pa.
Rochester, N. Y. **Dallas, Texas**

Cotton, Pierce, Streander, Inc.

Associated Consulting Engineers

E. R. Cotton E. M. Pierce
P. B. Streander G. A. Gieseke
I. J. Silverstone

Water Supply, Water Purification
Sewerage, Sewage Treatment
Refuse Disposal

P. O. Box 198 **132 Nassau Street**
Hyde Park 36, Mass. **New York 38, N.Y.**

DE LEUW, CATHER & COMPANY

Water Supply — Sewerage
Railroads — Highways

Grade Separations—Bridges—Subways
Local Transportation

Investigations—Reports—Appraisals
Plans and Supervision of Construction

150 N. Wacker Drive, Chicago 6
79 McAllister St., San Francisco 2

GARRITY & MOSHER

Engineers

Leo V. Garrity — L. W. Mosher

Municipal and Industrial Water and Sewage Works
Water System Analyses
Tunnels and Foundations
Reports, Designs, Plans and Specifications

14050 W. McNichols Rd., Detroit 35, Mich.

FAY, SPOFFORD & THORNDIKE

Engineers

John Ayer — Ralph W. Horne
Bion A. Bowman — William L. Hyland
Carroll A. Farwell — Frank L. Lincoln
Howard J. Williams

Water Supply and Distribution — Drainage — Sewerage and Sewage Treatment — Airports — Bridges — Turnpikes

Investigations Reports Designs Valuations
Supervision of Construction

Boston — New York

Glace & Glace, Inc.

Civil and Sanitary Engineers

Water Supply, Purification and Distribution,
Dams, Sewerage, Sewage and Industrial
Waste Treatment
Investigations, Reports, Designs
Supervision of Construction and Operation

1001 North Front Street, Harrisburg, Penna.
Wash., D.C.—Easley, S. C.—Tallahassee, Fla.

FINKBEINER, PETTIS & STROUT

Carleton S. Finkbeiner Charles E. Pettis
Harold K. Strout

Consulting Engineers

Reports, Designs, Supervision,
Water Supply, Water Treatment, Sewerage,
Sewage Treatment, Wastes Treatment,
Valuations & Appraisals

518 Jefferson Avenue — Toledo 4, Ohio

GREELEY AND HANSEN

Engineers

Water Supply, Water Purification
Sewerage, Sewage Treatment
Refuse Disposal

220 S. State Street, Chicago 4

FREESE & NICHOLS

Fort Worth, Texas

FREESE, NICHOLS & TURNER

Houston, Texas

Industrial and Municipal Engineering—Water Supply and Purification—Sewerage and Industrial Waste Treatment—Highways and Structures — Dams — Drainage Works — Airports—Investigations—Valuation—Design and Supervision.

WILLIAM F. GUYTON & ASSOCIATES

Consulting Ground-Water Hydrologists

Underground Water Supplies
Investigations, Reports, Advice

307 W. 12th St., Austin 1, Texas
Phone: GR-7-7165

3301 Montrose Blvd., Houston 6, Texas
Phone: JA-2-9885

FROMHERZ ENGINEERS

Structural—Civil—Sanitary

Four Generations Since 1867

Water Supply; Sewerage; Structures;
Drainage; Foundations

Investigations; Reports; Plans and
Specifications; Supervision

New Orleans

FRANK E. HARLEY, C. E.

Consulting Engineer

Water Supplies, Highways
Municipal Problems

260 Godwin Ave.
Wyckoff, N.J.

GANNETT FLEMING CORDDRY & CARPENTER, Inc.

Engineers

Water Works—Sewerage
Industrial Wastes—Garbage Disposal
Roads—Airports—Bridges—Flood Control
Town Planning—Appraisals
Investigations & Reports

Harrisburg, Pa. — Philadelphia, Pa.
Pittsburgh, Pa. — Daytona Beach, Fla.

HASKINS, RIDDLE & SHARP

Consulting Engineers

Water—Sewage & Industrial Wastes—Hydraulics
Reports, Design, Supervision of Construction,
Appraisals, Valuations, Rate Studies

1009 Baltimore Avenue — Kansas City 5, Mo.

Professional Services

THE JENNINGS-LAWRENCE CO.

Civil & Municipal Engineers
Consultants

Water Supply, Treatment & Distribution
Sewers & Sewage Treatment
Reports—Design—Construction

1392 King Avenue — Columbus 12, Ohio

HAVENS & EMERSON

W. L. Havens — A. A. Burger
J. W. Avery — H. H. Moseley
F. S. Palocsay — E. S. Ordway
F. C. Tolles, Consultant

Consulting Engineers

Water, Sewage, Garbage, Industrial Wastes, Valuations—Laboratories

Leader Bldg. CLEVELAND 14 — Woolworth Bldg. NEW YORK 7

JONES, HENRY & WILLIAMS

Consulting Sanitary Engineers

Water Works
Sewerage & Treatment
Waste Disposal

Security Bldg. — Toledo 4, Ohio

HAZEN AND SAWYER

Engineers

Richard Hazen — Alfred W. Sawyer

Water Supply and Sewage Works
Drainage and Flood Control

Reports, Design, Supervision of Construction and Operation
Appraisals and Rates

122 East 42nd Street — New York 17, N.Y.

HARRY J. KEELING

Consulting Engineer

Electrical—Mechanical—Corrosion

Investigations—Reports—Advisory Service
Mobile radio communication systems;
Special mechanical design problems;
Soil corrosion, Electrolysis,
Cathodic protection
of buried or submerged metal surfaces.

1718 Livonia Avenue — Los Angeles 35, Calif.

ANGUS D. HENDERSON

Consulting Engineer

Water Supply and Sanitation

330 Winthrop St. — Westbury, New York
210-07—29th Ave. — Bayside, New York

ENGINEERING OFFICE OF CLYDE C. KENNEDY

Richard R. Kennedy — Robert M. Kennedy

Investigation—Design
Water Supply — Water Purification
Sewage and Waste Treatment
Water Reclamation

604 Mission St. — San Francisco 5

HORNER & SHIFRIN

Consulting Engineers

W. W. Horner — E. E. Bloss — V. C. Lischer

Water Supply—Airports—Hydraulic Engineering—Sewerage—Sewage Treatment—Municipal Engineering—Reports

Shell Building — St. Louis 3, Mo.

MORRIS KNOWLES INC.

Engineers

Water Supply and Purification,
Sewerage and Sewage Disposal,
Industrial Wastes, Valuations,
Laboratory, City Planning

Park Building — Pittsburgh 22, Pa.

ROBERT W. HUNT CO.

Inspection Engineers

(Established 1888)

Inspection and Test at Point of Origin of Pumps, Tanks, Conduit, Pipe and Accessories

175 W. Jackson Blvd.
Chicago 4, Ill.
and Principal Mfg. Centers

KOEBIG & KOEBIG

Consulting Engineers Since 1910

Investigations, Reports,
Designs and Appraisals
Water Supply & Water Treatment
Sewerage & Sewage Treatment
Municipal Engineering
Industrial Buildings

3142 Wilshire Blvd., Los Angeles 5, Calif.

Professional Services

LEGGETTE, BRASHEARS & GRAHAM

Consulting Ground Water Geologists

Water Supply — Salt Water Problems
Dewatering — Investigations
Recharging — Reports

551 Fifth Avenue — New York 17, N. Y.

THE PITOMETER ASSOCIATES, INC.

Engineers

Water Waste Surveys
Trunk Main Surveys
Water Distribution Studies
Water Measurement & Special Hydraulic Investigations

50 Church Street — New York

METCALF & EDDY

Engineers

Water, Sewage, Drainage, Refuse and Industrial Wastes Problems
Airports — Valuations
Laboratory

Statler Building
Boston 16

LEE T. PURCELL

Consulting Engineer

Water Supply & Purification; Sewerage & Sewage Disposal; Industrial Wastes; Investigations & Reports; Design; Supervision of Construction & Operation

Analytical Laboratories

36 De Grasse St. — Paterson 1, N. J.

THE H. C. NUTTING COMPANY

Engineers — *Chemists*

Investigations—Reports
Water — Sewage
Soils — Foundations — Building Materials
Inspection — Testing

4120 Airport Rd. — Cincinnati 26, Ohio
2145 N. W. 2nd Ave. — Miami 37, Fla.

THOMAS M. RIDDICK

Consulting Engineer and Chemist

Municipal and Industrial Water Purification, Sewage Treatment, Plant Supervision, Industrial Waste Treatment, Laboratories for Chemical and Bacteriological Analyses

369 E. 149th St. — New York 55, N.Y.
MOtt Haven 5-2424

PARSONS, BRINCKERHOFF, HALL & MACDONALD

G. Gale Dixon, Associate
Wellington Donaldson, Staff Consultant

Water, Sewage, Drainage and Industrial Waste Problems.

Structures — Power — Transportation

51 Broadway — New York 6, N. Y.

RIPPLE & HOWE, INC.

Consulting Engineers

O. J. Ripple — V. A. Vaseen — B. V. Howe

Appraisals—Reports
Design—Supervision

Water Works Systems, Filtration and Softening Plants, Reservoirs, and Dams, Sanitary and Storm Sewers, Sewage Treatment Plants, Refuse Disposal, Airports

833—23rd St., Denver 5, Colo.

MALCOLM PIRNIE ENGINEERS

Civil & Sanitary Engineers

Malcolm Pirnie — Ernest W. Whitlock
Robert D. Mitchell — Carl A. Arenander
Malcolm Pirnie, Jr.

Investigations, Reports, Plans
Supervision of Construction and Operations
Appraisals and Rates

25 W. 43rd St. — New York 36, N. Y.

RUSSELL & AXON

Consulting Engineers

Civil—Sanitary—Structural
Industrial—Electrical
Rate Investigations

408 Olive St., St. Louis 2, Mo.
Municipal Airport, Daytona Beach, Fla.

Professional Services

ALDEN E. STILSON & ASSOCIATES
(Limited)
Consulting Engineers

Water Supply—Sewerage—Waste Disposal
Bridges—Highways—Industrial Buildings
Studies—Surveys—Reports

245 N. High St. Columbus, Ohio

J. HOMER SANFORD
Consulting Engineer—Hydrologist
36 Years of Groundwater Investigation

Groundwater Development, Recharge,
Dewatering and Salt Intrusion
Analysis of Available Supply and Safe Yield
Litigation Reports and Testimony

1 Ascan Avenue Forest Hills 75, N.Y.

J. STEPHEN WATKINS
J. S. Watkins G. R. Watkins
Consulting Engineers

Municipal and Industrial Engineering, Water Supply and Purification, Sewerage and Sewage Treatment, Highways and Structures, Reports, Investigations and Rate Structures.

251 East High Street Lexington, Kentucky
Branch Office
901 Hoffman Building Louisville, Kentucky

SCHAEFER & WALTON
Consulting Ground-Water Hydrologists

Investigations, Reports, Advice
on
Ground Water Development, Induced
Infiltration From Surface Streams,
Artificial Recharge, Dewatering.

16 Leland Ave. Telephone
Columbus 14, Ohio AMherst 8-3316

WESTON & SAMPSON
Consulting Engineers

Water Supply and Purification; Sewerage, Sewage and Industrial Wastes Treatment. Reports, Designs, Supervision of Construction and Operation; Valuations.
Chemical and Bacteriological Analyses

14 Beacon Street Boston 8, Mass.

J. E. SIRRINE COMPANY
Engineers

Water Supply & Purification,
Sewage & Industrial Waste Disposal,
Stream Pollution Reports,
Utilities, Analyses

Greenville South Carolina

WHITMAN & HOWARD
Engineers
(Est. 1869)

Investigations, Designs, Estimates, Reports and Supervision, Valuations, etc., in all Water Works and Sewerage Problems

89 Broad St. Boston, Mass.

SMITH AND GILLESPIE
Consulting Engineers

MUNICIPAL UTILITIES
AND PUBLIC WORKS

Complete Engineering Services

JACKSONVILLE, FLORIDA

WHITMAN, REQUARDT & ASSOCIATES
Engineers *Consultants*

Civil—Sanitary—Structural
Mechanical—Electrical
Reports, Plans
Supervision, Appraisals

1304 St. Paul St. Baltimore 2, Md.

STANLEY ENGINEERING COMPANY
Consulting Engineers

327 S. LaSalle Street Hershey Building
Chicago 4, Illinois Muscatine, Iowa

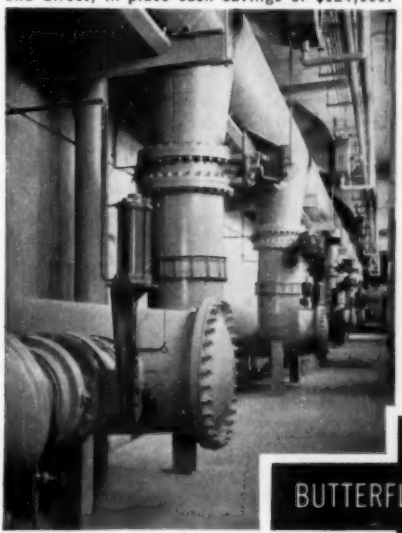
WILLING WATER
Public Relations Consultant

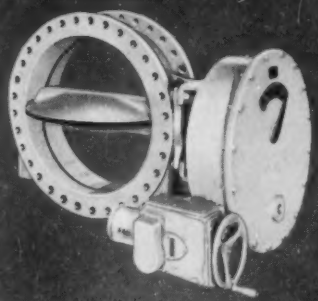
Willing Water cartoons available in low-cost blocked electrotypes and newspaper mats for use in building public and personnel good will.

Send for catalog and price list

American Water Works Association, Inc.
521 Fifth Avenue New York 17, N. Y.

DROP-TIGHT SHUTOFF R-S Rubber-Seated Butterfly Valves give drop-tight closure to 125 psig through wedge-type action of the disc within a one-piece rubber seat. 65 of these valves, installed as shown for service in the San Jacinto River project near Houston, gave a substantial space reduction and direct, in-place cash savings of $124,000.





FOR HIGH-PRESSURE SERVICE SMS Babbit-Seated Butterfly Valves are built to give tight shutoff and meet the rugged demands of high-pressure service. They are available for shutoff pressures up to 200 psig, and for a wide range of velocities, including open-end free discharge.

BUTTERFLY VALVES

GET POSITIVE SHUTOFF, CUT CONSTRUCTION COSTS

For high or low-pressure water service, SMS has the Butterfly Valve to give you tight shutoff and help reduce construction costs. Using SMS or R-S Butterfly Valves in place of conventional gate valves permits a much more compact piping layout, means substantial savings in the initial building costs. For full information on the complete SMS valve line — Butterfly Valves, Ball Valves and Rotovalves — see our local representative or write S. Morgan Smith Co., York, Pa.

HYDRAULIC TURBINES
GATES & HOISTS
TRASH RAKES
PUMPS
ACCESSORIES

HYDRODYNAMICS

ROTOVALVES
FREE-DISCHARGE VALVES
BALL VALVES
CONTROLLABLE-PITCH SHIP PROPELLERS
BUTTERFLY VALVES

S. MORGAN SMITH

AFFILIATE: S. MORGAN SMITH, CANADA, LIMITED • TORONTO

Condensation

Key: In the reference to the publication in which the abstracted article appears, **39**:473 (May '47) indicates volume 39, page 473, issue dated May 1947. If the publication is paged by the issue, 39:5:1 (May '47) indicates volume 39, number 5, page 1, issue dated May 1947. Abbreviations following an abstract indicate that it was taken, by permission, from one of the following periodicals: *BH—Bulletin of Hygiene (Great Britain); CA—Chemical Abstracts; Corr.—Corrosion; IM—Institute of Metals (Great Britain); PHEA—Public Health Engineering Abstracts; SIW—Sewage and Industrial Wastes; WPA—Water Pollution Abstracts (Great Britain).*

FOREIGN WATER SUPPLIES—GENERAL

Water Supply in Australia. W. MULLER. Gas- u. Wasserfach (Ger.), **95**:439 ('54). In Australia about 900 towns and communities have central water supplies, which supply about 75-80% of population. Total domestic and industrial demand is about 200 bil gal/yr and agricultural demand is about 400 bil gal/yr. Continent has large areas of desert land, avg rainfall is only 430 mm/yr and is very irregularly distributed, seepage and evaporation are high, accounting for about 397 mm of avg rainfall, and rivers in coastal areas are short and frequently intermittent. Only in coastal areas is there sufficient water for development of large cities. Most supplies are surface water, and construction of dams and impounding reservoirs is generally necessary. There are several regions with artesian water; methods of supplementing this have not so far been used. Waters collected from impounding reservoirs are generally of good qual. as drainage areas are usually kept free from habitation, but coagulation and filtration may be required to remove turbidity. Use of artesian waters is limited by high salt content. Description is given of water supply of Sydney, city of more than 2,000,000 inhabitants. Supply is drawn from impounding reservoirs in dists. rich in springs of unpol. water. Main source is spring waters forming source of Nepean R. This water is soft, slightly acid, and corrosive; typical anal. is given. Daily and seasonal variations in demand are described. —*WPA*

The Hamburg [Germany] Water Supply. W. DROBEK. Gas- u. Wasserfach. (Ger.), **95**:650 ('54). Attempt has been made to interconnect and unify 17 different water works supplying Hamburg. Greatly increasing demand has caused some difficulties in supplying satisfactory drinking water. At one plant, increasing hardness and Mn and Fe content required mech. breaking up of sand filter bed before it could be cleaned and addn. of $Ca(OH)_2$ to raw water before filtration. Use of Elbe River water has been necessary; rather high contamn. of this water has required special means to secure potable water; treatment of water with $Al_2(SO_4)_3$ and $FeCl_3$ prior to filtration, addn. of powd. C, and intensive chlorination have been necessary, but during few winter days, water is unsatisfactory from taste and color standpoint. Expts. with combined use of Cl and ClO_2 for elimg. residual taste were not successful. Several adsorbents offer promise for removal of residual taste and odor. At-

(*Continued on page 64 P&R*)

For Organic Iron and Color Removal—Algae Control—Regeneration of Iron Removal Filters—

Use

POTASSIUM PERMANGANATE

Supplied to industry and municipalities in various grades and meshes to fit the particular operation efficiently and economically in combating many water problems.

WRITE FOR QUOTATIONS

CARUS CHEMICAL COMPANY

Box JAW LaSalle, Illinois

For water supply Armco Pipe Serves cities best

NORTHWEST. Small crew installs Armco Water Pipe at Kennewick, Washington. Pipe is 16 inches in diameter with a 3/16-inch wall.

SOUTHEAST. Installing part of the more than 8 miles of 16-inch Armco Pipe for the Newberry, South Carolina, water line.

The many benefits you get with Armco Steel Water Pipe add up to low installed cost and low operating costs. You are assured of long-lasting, trouble-free service. Here are the quick facts on Armco Steel Pipe.

Sizes

Twenty diameters from 6 to 36 inches; ten wall thicknesses from 9/64 to 1/2-inch; exact lengths up to 50 feet.

Joints

Pipe ends can be flanged, beveled for field welding, prepared for Dresser couplings or otherwise finished to meet your needs. Standard or special fittings are fabricated to your plan.

Coatings and linings

Spun coatings and linings and outside protective coatings meet A.W.W.A. Specifications C-202 and C-204.

Write for more data. Armco Drainage & Metal Products, Inc., Welded Pipe Sales Division, 5136 Curtis Street, Middletown, Ohio. Subsidiary of Armco Steel Corporation. In Canada: write Guelph, Ontario.

ARMCO Welded Steel Pipe
Meets A.W.W.A. Specifications

ARMCO®

WHEREVER WATER FLOWS, STEEL PIPES IT BEST

(Continued from page 62 P&R)

tempts to reduce contamn. of Elbe above city have been partly successful. Service pipes used in Hamburg include Pb, Cu, and cast-iron pipes. Unprotected steel is rapidly corroded, and water quickly removes Zn coating from galvanized Fe; for services under 2 in., plastic pipe offers promise but requires improvement before full use can be made. Pb is not believed to offer health hazard; when pipe is new, water standing in Pb pipe overnight should be discarded; lab. tests are being carried out to det. actual amt. of Pb dissolved under such conditions. —*CA*

The Preparation of Part of the Kassel Water Supply [Germany]. H. HUGELMANN. Gas- u. Wasserfach. (Ger.), **96**:315 ('55). Part of Kassel water supply is produced from deep wells; water from part of these wells contains considerable Fe, and in some cases Mn. These compds. are removed by aeration, settling, and filtering through rapid filters. Water from some wells contains enough CO_2 to cause corrosion, especially in presence of O from aeration. Additions of Na_2HPO_4 at rate of 3.5 mg P_2O_5 and later at rate of 1.5 mg were made in order to form a coating on interior of water main. Although fairly good coating was formed after some months, pitting still occurred owing to pustules contg. sulfides, and Fe bacteria (*Gallionella*). In future, sulfate-reducing bacteria will be destroyed by chlorination to facilitate formation of uniform coating of phosphate. Brief reference is made to fluoridization of water.—*CA*

Ground Water for the Supplementary Supply of Salzburg [Ger.]. F. SITTE. Gas, Wasser, Warme, **9**:171 ('55). Satisfactory supplies of ground water can be secured from ground-water fields in Salzburger Zungenbeckens at much lower cost than supply from Fuschlsee. In addn., supply can be developed in stages. Only disadvantage is somewhat high hardness (18 German degrees of hardness).—*CA*

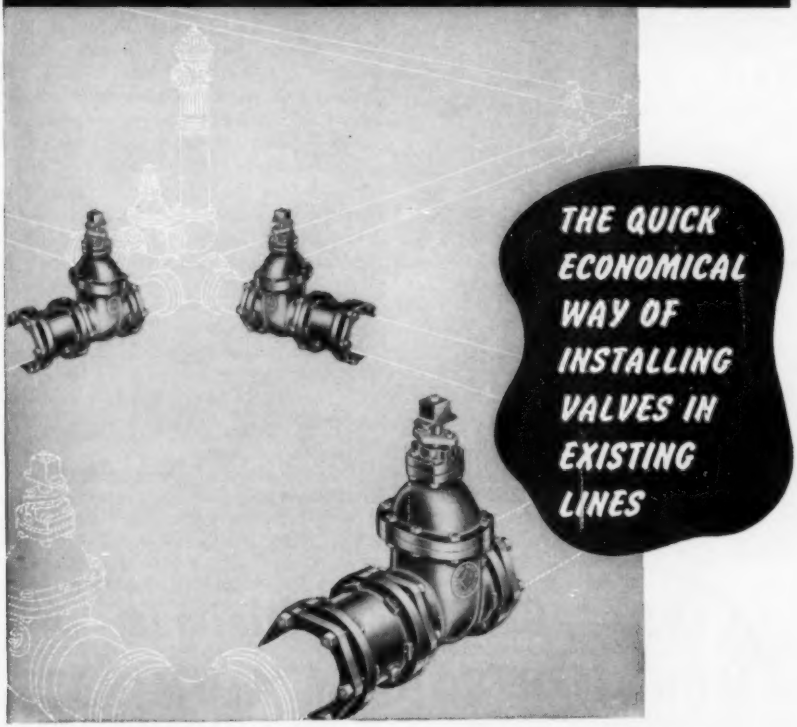
(Continued on page 66 P&R)

MUNICIPAL SUPPLIES
No. 152
ESTABLISHED 1908—47 YEARS OF SERVICE
W.S. DARLEY & CO
CHICAGO 12 ILLINOIS
WRITE TODAY
For
100 PAGE CATALOG
W. S. DARLEY & CO. Chicago 12

Switch to
ANTHRAFILT
the MODERN
All-Purpose Filtering Medium
Anthrafilt Offers Many Advantages Over Sand and Quartz
- DOUBLES length of filter runs.
- REQUIRES only half as much wash water.
- KEEPS Filters in service over longer periods.
- INCREASES Filter output with better quality effluent.
- GIVES better support to synthetic resins.
- PROVIDES better removal of fibrous materials, bacteria, micro-organic matter, taste, odor, etc.
- IDEAL for industrial acid and alkaline solutions.
- EFFECTIVE filtration from entire bed.
- LESS coating, caking or balling with mud, lime, iron, or manganese.

Write for further information, test samples and quotations to:
PALMER FILTER EQUIPMENT CO.
P.O. Box 1696—822 E. 8th St., Erie, Pa.
Representing:
ANTHRACITE EQUIPMENT CORP.
Anthracite Institute Bldg., Wilkes-Barre, Pa.

SMITH CUT-IN VALVE AND SLEEVE



The Smith Mechanical Joint Cut-in Valve and Sleeve is truly the answer to the problem of installing gate valves in existing piping which can be relieved of pressure. The design reduces size of excavations, installation time and in-service cost to the minimum. Two substantial stop screws lock the Valve and Sleeve securely in place.

The Cut-in Valve and Sleeve can be installed on any standard class of cast iron pipe. Molded rubber gaskets fit into machined "Stuffing Box Type" joints, which are permanently leak proof. Smith Cut-in Valves are manufactured in compliance with the A.W.W.A. gate valve specification. Write for Bulletin MJ2.

55

FIRE HYDRANTS · VALVES · SINCE 1896

THE A.P. SMITH MFG. CO.

EAST ORANGE, NEW JERSEY

(*Continued from page 64 P&R*)

Manila's [P.I.] Great Water Supply System Started With Bequest of 10,000 Pesos Left by Francisco D. Carriedo in 1773. Am. Pipe Progress, **39**:12 (3rd Quarter '54). One of world's safest and purest water supplies was started in 1867 with proceeds of bequest of 10,000 pesos left Manila by Francisco D. Carriedo 90 yr earlier. System, using Marikin R. at Santolan, began supplying water at rate of 160,000 gpd in August 1882. Later, with installation of pumps, capac. was increased to 2.5-mgd rate. Further addns. to pump capac. increased output to 8 mgd. At beginning of American regime in Philippines, Montalban R. was tapped, and in 1909 system was increased to 23 mgd at cost of 6,000,000 pesos. In 1912, original supply from Marikin R. was 31 mgd. New source, Angat R., further increased supply to 80 mgd at cost of over 11,000,000 pesos. Distr. system was built entirely of cast-iron pipe and late addns. of 42" monocast centrifugal pipe. Water furnished by Manila Metropolitan Water Dist. more than meets purity stds. of USPHS, and consumer cost per unit of water is nearly half that paid by residents of American cities of comparable population.—*PHEA*

The Water Clarification Plant of Minas de Penouta [Spain]. A. A. Buylla. Química e industria (Span.), **2**:232 ('55). Conservation of important salmon and trout fishing industry imposes major problem on Minas de Penouta in restoring water used in its scheelite concg. plant to original purity before discharge into Navia River. In purifying system that operates either in closed or open circuit, as occasion demands, water is pumped from primary pond supplied from river to elevated reservoir of 200-cu m capacity from which flow goes directly to ore washer. Tailings and waste water are sepd. with drag classifier, and water after treatment with $Ca(OH)_2$ flows to flocculator for avg detention of 30 min. Clarified water is pumped to main reservoir while underflow sludge goes to series of decanters also discharging overflow to stor-

(*Continued on page 68 P&R*)

95% Guaranteed Minimum

MONOLITH SODIUM ALUMINATE

for water clarification & softening

Only Monolith offers this 95% sodium aluminate with added advantage of correspondingly low insoluble content. Thus Monolith goes farther. A 90% grade is also available.

Monolith quickly forms a dense, rapid settling floc which produces bright effluent ideal for filtering.

Low excess soda gives less susceptibility to caking . . . gives more feeder and chemical efficiency.

Comparison . . .

A check of the percentage strength you may be using will prove that Monolith and ONLY Monolith offers 95% minimum concentrate.

Write for samples and prices

and the name of our distributor nearest you.

MONOLITH PORTLAND MIDWEST CO.

Oxide Division

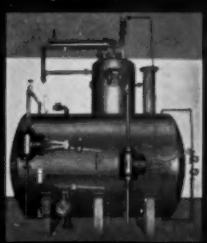
Tramway Bldg. • AMherst 6-1933 • Denver 2, Colo.

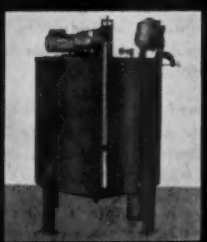
Manufacturers of Portland Cement for over 25 years. Plants in California and Wyoming

MP6-1

what's the cost in the long run?

There's no dodging the question today. High costs and low budgets demand straight answers. The installation of water conditioning equipment is an important step that merits the careful consideration of every factor involved. Modern General Filter water conditioning installations are designed with a practical eye on original equipment and installation costs. Equally important, however, is the extent of continuing service available from the company with which you are dealing. General Filter's staff of highly trained engineers and chemists are at your call on a moment's notice. General Filter's 40 branches are located across the country to give you prompt dependable service. Make your own comparisons and you will join the hundreds of General Filter water treatment plants that are enjoying lower first cost—lower operating costs—lower maintenance costs.





General Filter Company
AMES, IOWA
... better water

SERVICES INCLUDE

Removal of
- ODORS
- IRON RUST
- HARDNESS
- TURBIDITY
- ALL MINERALS
- ALKALINITY
- INDUSTRIAL WASTE TREATMENT

EQUIPMENT INCLUDES

- Flash Mixers and Flocculators
- Upflow Sludge Clarifiers
- Swimming Pool Filters
- Rapid Sand Filters
- Diatomite Filters
- Flow Indicators and Controllers
- Filter Underdrain Systems
- High Capacity Resinous Zeolite

(*Continued from page 66 P&R*)

age. Mech. constr. is described in detail. —*CA*

The Content of Bacteria and Character of Water in the Recently Discovered Part of the Lummelunda Cave, Gotland [Sweden]. H. HINRICSSON. Geol. Foren. i Stockholm Fohr. (Swed.), **77**:633 ('55). Results of bacteriol. and chem. anals. of the H_2O are presented. They indicate that H_2O is nonsterile and spring H_2O with chem. compn. peculiar to H_2O of limestone areas flows through Lummelunda cave.—*CA*

Hot Waters in the Valley of the River Manych [USSR]. S. M. DRACHEV. Gidrokhim. Materialy (Russ.), **22**:57 ('54). 2 ponds, 200 × 30 m and 100 × 20 m, about 2 m deep, were investigated for temp. and mineral content. Temp. at surface during Aug., 1950, was 25.5°, at 80-cm depth 50.3°, and at 150-cm depth 55.7°. Mineral content varied from 0.83 g-equiv. of Cl, 0.25 SO_4, 0.18 Ca + Mg, and 0.90 K + Na at 50-cm depth to 2.73, 2.17, 0.91, and 4.0, resp., at 150-cm depth. Bottom muds have no gaseous phase and temp. is 49.8°, lower than temp. of lower layer of water.—*CA*

Hydrochemical Characteristic of the Ponds in the Arid Regions of the Rostov Province [USSR]. N. V. VESELOVSKII, M. P. GOLOVKOV & M. N. TARASOV. Gidrokhim. Materialy (Russ.), **22**:23 ('54). Of 186 ponds sampled in 1949 and 1950, during months of Jun. to Aug. when salt content is stationary, 109 belong to sulfate class. They vary in salt content from 447 to 21,000 mg/l; 26 ponds belong to chloride-sulfate class, with 1,200 to 21,300 mg/l; 28 ponds belong to chloride class, with 1,200 to 21,300 mg/l; 20 ponds belong to bicarbonate class, with salt content varying from 184 to 595 mg/l. Some ponds vary more than limits given. Data are given on chloride, sulfate, carbonate, bicarbonate, Mg, Ca, and Na + K of 13 ponds of respective classes, as well as compn. of wells, rivers, and lakes in province. Map of province gives distribution of these

(*Continued on page 70 P&R*)

Type SM with Worm Gear Drive on Butterfly Valve.

Limitorque® VALVE CONTROLS

From coast to coast, hundreds of LimiTorque Controls are in service in central stations and power plants for automatic or push-button operation of valves up to 120 inch diameter. Why is acceptance so widespread? Because LimiTorque Operators are designed to provide dependable, safe and sure valve actuation at all times.

LimiTorque is self-contained and is applicable to all makes of valves. Any available power source may be used to actuate the operator: Electricity, water, air, oil, gas, and are readily adapted to Microwave Control.

A feature of LimiTorque is the torque limit switch which controls the closing thrust on the valve stem and prevents damage to valve operating parts.

Write for Catalog L-550

Philadelphia Gear Works, Inc.

ERIE AVE. and G STREET, PHILADELPHIA 34, PA.

NEW YORK • PITTSBURGH • CHICAGO • HOUSTON • LYNCHBURG, VA. • BALTIMORE • CLEVELAND

WATER USE TO REACH ALL-TIME HIGH THIS SUMMER

will your revenue keep pace?

The answer is yes IF your water meter is CALMET. Standardize on CALMET *today*.

CALMET WATER METER

MANUFACTURED BY
WELL MACHINERY & SUPPLY CO., INC.
FORT WORTH, TEXAS

(Continued from page 68 P&R)

different classes of mineralization in ponds. Salt regime of no. of ponds sampled in 1951–52 giving limits of chloride and sulfate is also presented, as well as that of chief ions as reported on waters of other ponds. The O_2, CO_2, oxidation, and biogenic substances are discussed. The waters are classified on basis of ions present. 26 references. —*CA*

BACTERIOLOGY

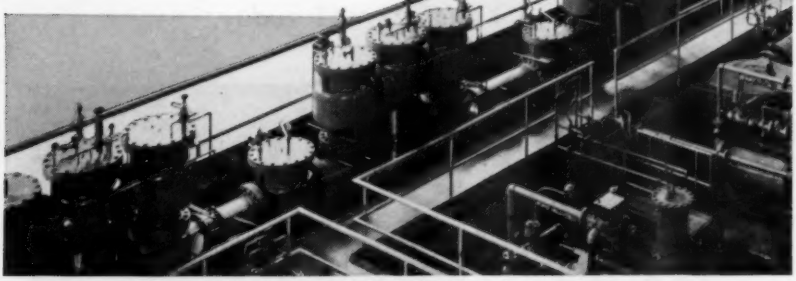
Thermal Inactivation of a Bacterium-Bacteriophage System. A. BUZZELL, D. TRKULA & M. A. LAUFFER. Arch. Biochem. Biophys., **49**:234 ('54). Thermal inactivation of complex formed by *Esch. coli* B and phage *T2r* was investigated to det. how stability of complex varies as growth of phage progresses. Rate of inactivation of complex at 47°C was much higher than rate of inactivation of free bacteria or free phage and increased with increase in period of incubation of complex at 37°C. Complexes developed for 14 min or more at 37°C burst and released active phage particles immediately on heating at 47°C. It appears that premature lysis is induced by heating.—*WPA*

Studies on the Filamentous Sheathed Iron Bacterium *Sphaerotilus Natans*. J. L. STOKES. J. Bacteriol., **67**:278 ('54). Pure cultures of filamentous sheathed iron bacterium *Sphaerotilus natans* were isolated from water in streams, ponds, and ditches. 2 types of colonies were observed, 1 type which appeared rough and was composed mainly of filaments, and 1 which appeared smooth and glistening and was composed of single cells. Filaments are formed from chains of rod-shaped cells in closely fitting sheaths. Individual cells when set free are motile with tuft of spirally coiled flagella. *S. natans* is capable of utilizing large variety of org. compds. as sources of C and energy and can use ammonium salts, nitrates, individual amino acids, and complexes such as peptone and meat extract as sources of nitrogen. No external supply of growth factors is required. All strains of organism are capable of growth over range of temp. 15°C–40°C and of pH value of 5.8–8.1. Optimum

(Continued on page 72 P&R)

At the Bryant Street Pumping Station in Washington, D. C.
"The most modern pumping station in the world today"

28 GOLDEN-ANDERSON
Automatic 16 inch VALVES



4-page folder describing this installation gladly sent on request.
GOLDEN-ANDERSON VALVE SPECIALTY CO., 1221 Ridge Ave., Pittsburgh 33, Pa.

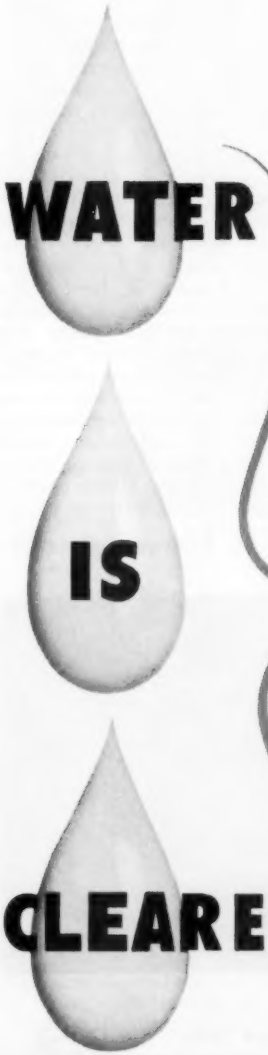
First Choice Coagulant of Most American Municipalities

For Water Treatment

Produces crystal-clear water
Gives better floc formation
Promotes better settling and longer filter runs
Aids in reduction of tastes and odors
Has no chlorine demand
Is a low-cost coagulant
Superior in tests against other coagulants
High in quality. Its constant uniformity can be depended upon

Also—for Sewage Treatment

Clean, easy to handle
Dry feeds well or dissolves readily for solution feeding; liquid alum also available in many areas
Clear, colorless effluents are possible
Simple application. Requires only low-cost feeding apparatus and minimum attention
Sludge digests readily
Treated digested sludge dries quickly with a minimum of odor
Chlorine consumption is cut due to lower demand of clarified sewage
Economical to use



treated with

GENERAL CHEMICAL "ALUM"

PRODUCED NEAR YOU! General Chemical's network of 25 Aluminum Sulfate plants assures prompt shipment anywhere, anytime. Here is a source to rely on . . . in day-to-day operations *and in emergencies!* From every standpoint, General Chemical Alum is the wise choice in coagulants. Make it yours!

Basic Chemicals for American Industry

GENERAL CHEMICAL DIVISION
ALLIED CHEMICAL & DYE CORPORATION
40 Rector Street, New York 6, N. Y.

Offices: Albany • Atlanta • Baltimore • Birmingham • Boston • Bridgeport • Buffalo Charlotte • Chicago • Cleveland • Denver • Detroit • Greenville (Miss.) • Houston Jacksonville • Kalamazoo • Los Angeles • Milwaukee • Minneapolis • New York Philadelphia • Pittsburgh • Providence • San Francisco • Seattle • St. Louis • Yakima (Wash.)
In Canada: The Nichols Chemical Company, Limited • Montreal • Toronto • Vancouver

(*Continued from page 70 P&R*)

growth occurs at 30°C in neutral or slightly alk. medium. No growth occurs under completely anaerobic conditions, but growth does take place in presence of small amts. of oxygen. Oxidative metabolism of nonproliferating cell suspensions of organism was investigated. Photographs of stained and living cells included.—*WPA*

The Problem of the Mechanism of the Action of Supersonic Waves on Bacteria. H. LUBKE. Z. Hyg. Infektionskrankh. (Ger.), **138**:216 ('53). Investigations have suggested that action of supersonic waves on bacteria is mainly mech., but it is not yet clear what part thermal and chem. effects play. Author describes expts. to det. time required for destruction of *Esch. coli*, on effect of content of gas and of viscosity of medium in which bacteria were suspended and on influence of size, form, and resistance to heat of various bacteria on action of supersonic waves. App. in which bact. suspension was kept at even temp. during application of waves by immersing tube in flowing water is described. Application of supersonic waves to suspensions of *Esch. coli* showed that at first numbers destroyed were relatively large; with increasing period of treatment, however, effect became less, and complete destruction was not obtained even after 60 min. Content of gas in liquid in which bacteria were suspended had considerable influence but cannot be regarded as main factor, as some destruction took place even in almost completely degasified suspensions. With coliform bacteria, no. of surviving bacteria had almost linear relation to concn. of dextrose soln. used for suspension; it is suggested that possibly lower gas content of more concd. solns. may play some part in weakening action of waves. Expts. with 10 different types of bacteria designed to find effects of size, form, and resistance to heat on sensitivity to supersonic waves did not lead to any definite conclusions, and it appears that bact. surfaces and boundary surfaces are of influence. Author concludes that action cannot be explained by thermal or chem. influences and must be largely of mech. nature.—*WPA*

ELEVATED TANKS

For almost a century Cole elevated tanks have been helping provide uniform water pressure, fire protection and adequate water reserve in scores of American cities.

Capacities 5,000 to 2,000,000 gallons—with hemispherical, ellipsoidal or conical bottoms. Also flat-bottom tanks for standpipe storage. Correctly built in accordance with AWWA specifications.

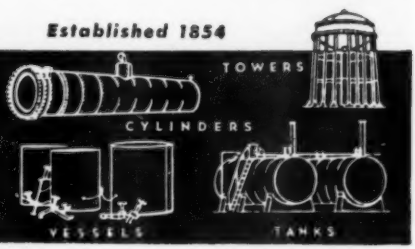
We invite your inquiries. State capacity, height to bottom, and location.

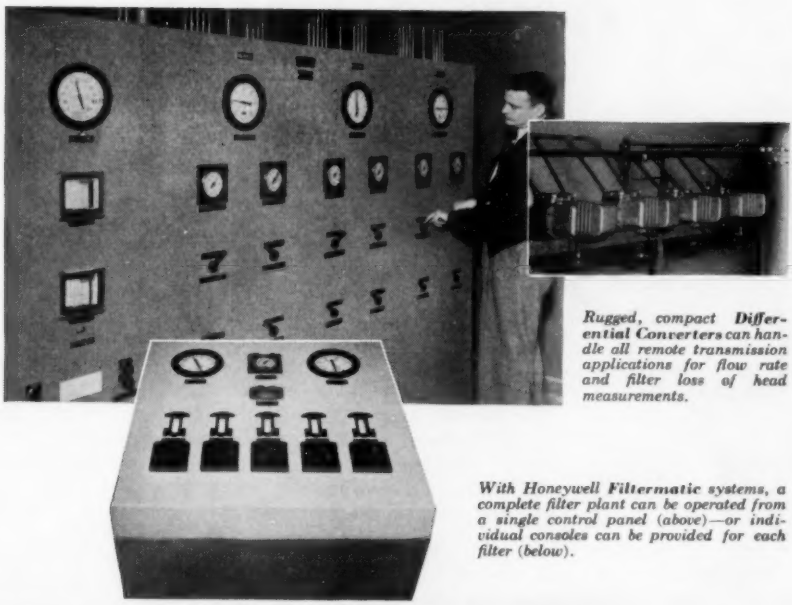
R.D. COLE

MANUFACTURING CO.

NEWNAN, GA.

Established 1854





Rugged, compact ***Differential Converters*** *can handle all remote transmission applications for flow rate and filter loss of head measurements.*

With Honeywell ***Filtermatic*** *systems, a complete filter plant can be operated from a single control panel (above)—or individual consoles can be provided for each filter (below).*

Honeywell *Filtermatic** Systems give you *centralized automatic* control of your filtration plant

You can put a new kind of operating economy and simplicity into your water filtration plant, with Honeywell *Filtermatic* systems.

Flexible control. Operator can select manual, semi-automatic or remote manual control of filtering and backwashing. Or he can have automatic control established by pre-set flow rates, clearwell level or water usage.

Flexible design . . . no limitations of cables and mechanical linkages. You can have central control panels in lab or office, or individual operating consoles on the filter floor.

Simple installation. Compact components save space, fit anywhere. First cost is low, installation is easy.

Simple maintenance. *Filtermatic* systems function continuously with minimum attention. Use of interchangeable units cuts spare parts inventory. Pipe galleries stay clean and corrosion problems are reduced, because clean, dry air is used. For full facts, call your local Honeywell sales engineer . . . as near as your phone.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, Wayne and Windrim Avenues, Phila. 44, Pa. —in Canada, Toronto 17, Ontario.

MINNEAPOLIS **Honeywell**

BROWN INSTRUMENTS

First in Controls

*Trademark of Minneapolis-Honeywell Regulator Co.

Allis-Chalmers Helps Increase WATER to meet increasing needs of Niteroi, Brazil

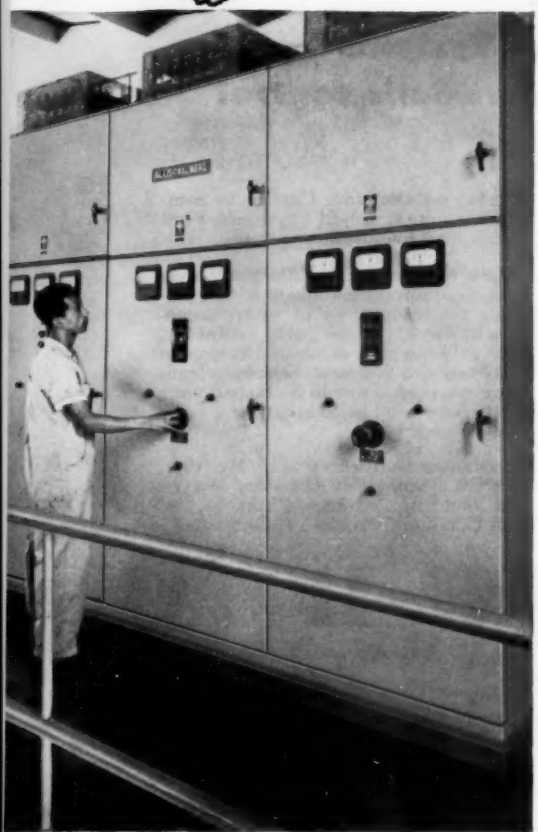
Across the bay from Rio de Janeiro, the busy water-front city of Niteroi and its suburban areas needed more and better water to meet growing industrial and metropolitan requirements.

Untreated water was furnished from protected reservoirs — top capacity was 4500 gpm for almost 300,000 population.

Because of this, a new water system was installed, including a complete treatment plant and reservoir, with a direct-fall supply to the city in potential capacity of 16,000 gpm —an increase of over 250%. At present the system is putting out 9500 gpm, at an average 100 lb pressure, pending improvements in city mains and sewer system.

Two pumping stations supply Niteroi: Imunana, a new site on the river; and Laranjal, handling water from the mountains. Allis-Chalmers pumps, motors and control, installed and operating at both stations, furnish the greatly increased amount of water needed.

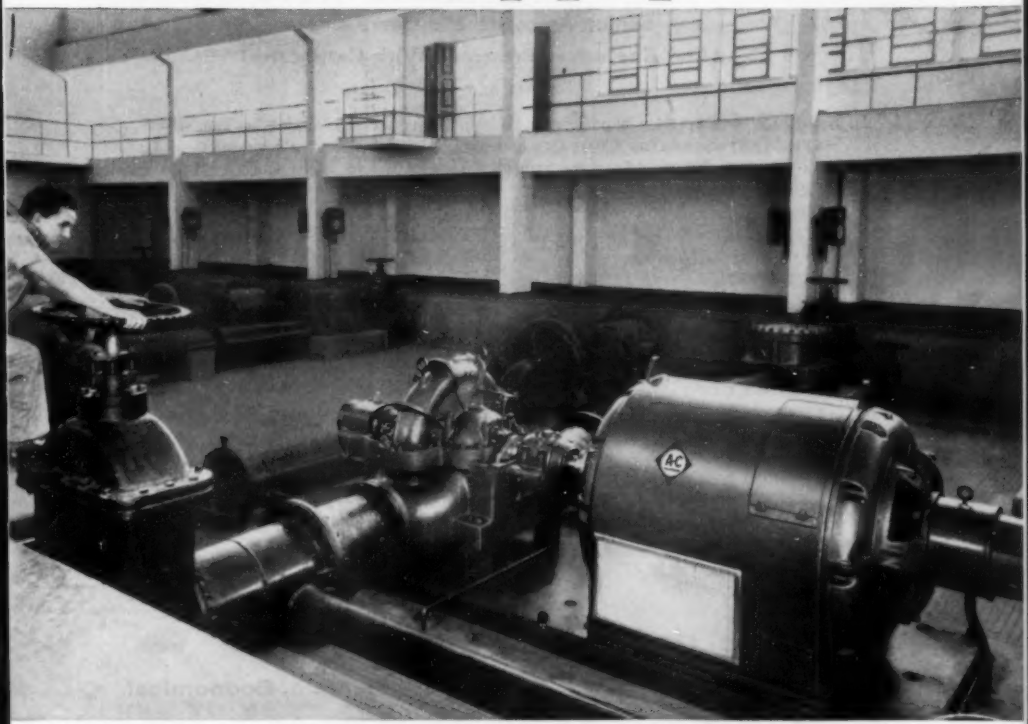
When YOUR CITY plans expansion or modernization, do as progressive communities all over the world are doing—call your nearest A-C office or write Allis-Chalmers, General Products Division, Milwaukee 1, Wisconsin. A-4950



Allis-Chalmers control lineup at Laranjal Station features three Type HARS-70 starters. Starters at Imunana Station are identical, used with Allis-Chalmers 500-hp synchronous motors.

ALLIS-

Equipment
Water Supply 250%



Three Allis-Chalmers 16 by 14-inch Type SI pumps, rated 7926 gpm, 295-ft head, are driven at 1200 rpm by Allis-Chalmers 800-hp, drip-proof, end-shield bearing synchronous motors. Laranjal Station is pictured—installation at Imunana is similar.

Exterior view of Laranjal Station. This contemporary building contains pumping units and operation offices. Modern housing units built at each station accommodate operating personnel.

Allis-Chalmers Builds the World's Largest Range of Equipment for Public Works

Pumps; motors, *Texrope* drives, control; switchgear, substations, transformers; butterfly valves; steam turbine-generator units, condensers, hydraulic turbines and generators, engine-generator units; blowers, compressors, vacuum pumps; dryers, screens, mills, sifters; tractors, graders, scrapers, motor wagons, power units.

Texrope is an Allis-Chalmers trademark.

CHALMERS

A-C ALLIS-CHALMERS

(Continued from page 48 P&R)

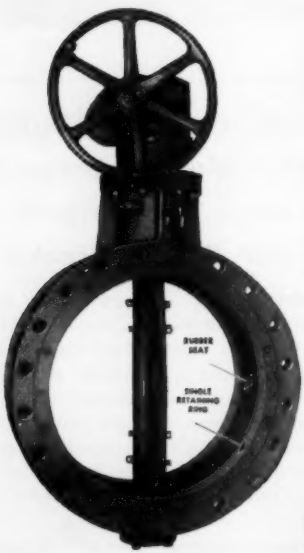
Senior Associate Member Firms
(And Executives Presented With Certificates)

(See story on p. 38 P&R)

1882 Bingham & Taylor Corporation, Joe H. Gardner, President & Treasurer
1882 Hays Manufacturing Company, William Hays Forster, President
1882 The Ludlow Valve Manufacturing Company, Inc., Oliver F. Gang, President & General Manager
1882 Mueller Co., Albert G. Webber Jr., President
1882 National Meter Division of Rockwell Manufacturing Company, W. F. Rockwell, Board Chairman
1884 The Bourbon Copper & Brass Works Company
1884 The Chapman Valve Manufacturing Company, Frank Hunter, Vice-President —Sales
1884 R. D. Wood Company, T. V. Wood, Vice-President
1884 Worthington Corporation, C. K. Hood, Vice-President
1885 James B. Clow & Sons, Inc., John Madden, President
1885 National Tube Division, United States Steel Corporation, H. J. Wallace, Vice-President—Sales
1885 Eddy Valve Company, Division of James B. Clow & Sons, Inc., John Madden, President
1887 Hersey Manufacturing Company, Walter A. Hersey, President
1890 Rensselaer Valve Company, Division of the Ludlow Valve Manufacturing Company, Inc., Oliver F. Gang, President & General Manager

(Continued on page 78 P&R)

Positive drop-tight shut-off



Easy . . . Efficient . . . Economical with

LEOPOLD
Rubber Seated
BUTTERFLY VALVES

In this design, the seat is of resilient neoprene rubber or pure gum rubber, vulcanized around a steel ring insert, and held in place by a keeper ring. The steel ring, which is "continuous" to eliminate abnormal wearing, increases the firmness of the seat and assures longer service life.

Whether operated manually or by automatic controls, Leopold Butterfly Valves always provide a positive shut-off that's bubble-tight. Made in sizes 6" to 72".

Leopold *Write today for descriptive literature!*

F. B. LEOPOLD CO., INC.
2413 W. CARSON STREET, PITTSBURGH 4, PA.

COMPLETE WATER PURIFICATION AND FILTER PLANT EQUIPMENT • BUTTERFLY VALVES
FILTER OPERATING TABLES • MIXING EQUIPMENT • DRY CHEMICAL FEEDERS

WORTHINGTON-GAMON

WATCH DOG

The meter used by thousands of municipalities in the U. S.

WATER METERS

"Watch Dog" models . . . made in standard capacities from 20 g.p.m. up: frost-proof and split case in household sizes. Disc, turbine, or compound type.

SURE TO MEET YOUR SPECIFICATIONS FOR ACCURACY, LOW MAINTENANCE, LONG LIFE.

Before you invest in water meters, get acquainted with the design and performance advantages which make Worthington-Gamon Watch Dog Water Meters first choice of so many municipalities and private water companies in the United States.

WORTHINGTON-GAMON METER DIVISION

Worthington Corporation

296 SOUTH STREET, NEWARK 5, NEW JERSEY

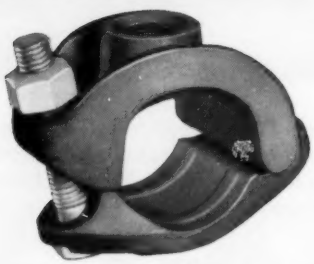
OFFICES IN ALL PRINCIPAL CITIES

(Continued from page 76 P&R)

1891 Ross Valve Manufacturing Company, William F. End, Treasurer & General Manager
1891 The Thomson Meter Corporation, John J. Carroll, Sales Manager
1892 The Farnan Brass Works Company
1892 U.S. Pipe & Foundry Company, Carl N. Brown, Sales Manager
1894 Neptune Meter Company, Wentworth Smith, Vice President
1897 The A. P. Smith Manufacturing Company, H. F. O'Brien, President
1898 Pittsburgh Equitable Meter Company, Division of Rockwell Manufacturing Company, W. F. Rockwell Jr., President
1898 Lead Lined Iron Pipe Company, J. D. Dwyer Jr., Vice-President
1901 B-I-F Industries, Inc., George W. Kelsey, Vice-President
1902 General Chemical Division, Allied Chemical & Dye Corporation, Chester M. Brown, President
1903 The Central Foundry Company, L. E. Desmond, Sales Manager
1904 Badger Meter Manufacturing Company, J. O. Wright, President
1904 Dresser Manufacturing Division, Dresser Industries, Inc., H. Z. Hight, Sales Manager
1905 Allis-Chalmers Manufacturing Company, C. W. Schweers, Vice-President
1905 Buffalo Meter Company, C. K. Bassett, Vice-President
1906 American Cyanamid Company, David Lurie, Technical Director
1906 National Water Main Cleaning Company, J. A. Frank, Vice President & General Manager
1906 The Pitometer Associates, Inc., C. R. Bird, Vice-President & Western Manager
1907 American Cast Iron Pipe Company, J. W. MacKay, Vice-President
1907 Glamorgan Pipe & Foundry Company, W. Neil Hammerstrom, Eastern Sales Manager

(Continued on page 80 P&R)

FOR MAKING SERVICE CONNECTIONS



Skinner Seal Service Saddle for steel, cast iron and transite pipe. Single massive bolt speeds and simplifies installation. Write today for new catalog.

M. B. SKINNER COMPANY
SOUTH BEND, INDIANA

LaMOTTE CONTROLS

have served the Water Works Engineer for more than 35 years.

Have you sent for the latest booklet on this helpful LaMotte Service?

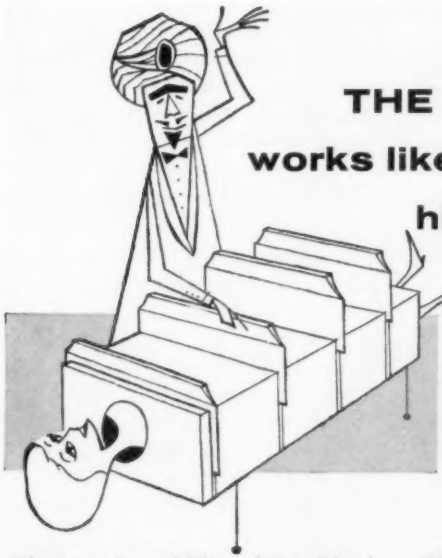
For example—did you know that the LaMotte-Pomeroy Sulfide Testing Outfit determines accurately:

• Total Sulfides • Dissolved Sulfides • Hydrogen Sulfide in Sludges and Solutions • Free Hydrogen Sulfide in Air and Gases? •

We will be happy to send full information on this and other LaMotte units used in the Water Works field.

LaMOTTE CHEMICAL PRODUCTS COMPANY

Dept. AWWA Chestertown, Md.



THE REX VERTI-FLO works like magic in cutting high settling costs

The amazing ability of Rex Verti-Flo Clarifiers to reduce costs... assure clearer effluent... increase over-all plant efficiency... is almost magical. Actually the Verti-Flo design *divides* a horizontal-flow settling tank into a series of smaller, vertical-flow cells.

These Verti-Flo users are getting increased efficiency... lower costs... clearer effluent

Fairmont, Minn.	Sweet Home, Oregon
U. S. Penitentiary, McNeil Island, Wash.	Fort Wayne, Indiana
Ashland, Oregon	Belleview, Wash.
Roseburg, Oregon	Washington Water Power Co. Clarkston, Wash.
Kansas State Penitentiary, Lansing, Kansas	Somerset, Penn.
Corvallis, Oregon	Federal Reformatory for Women Alderson, W. Va.
Florence, Oregon	
Valencia, Venezuela	

What does this unique design mean? It means more tank capacity—up to *four* times more than conventional settling tanks. In existing tanks, Verti-Flo will at least double your present capacity. In new construction, Verti-Flo® saves on both construction and equipment costs since you can plan for smaller tanks. Detention times are from one-fourth to one-half those required in conventional tanks and yet you get an effluent of maximum clarity.

Whether you specify equipment or operate a plant, you should know the facts about Rex® Verti-Flo. Why not have the advantages of Rex® Verti-Flo in your plant? For complete details, mail the coupon today for your copy of Bulletin 52-77. You'll be happy you did.

CHAIN BELT COMPANY
Milwaukee 1, Wis.

CHAIN Belt Company
4609 W. Greenfield Ave.
Milwaukee 1, Wis.

Send me my copy of informative Verti-Flo Bulletin No. 52-77.

Name.....
Title.....
Address.....
City.....*State*.....

(Continued from page 78 P&R)

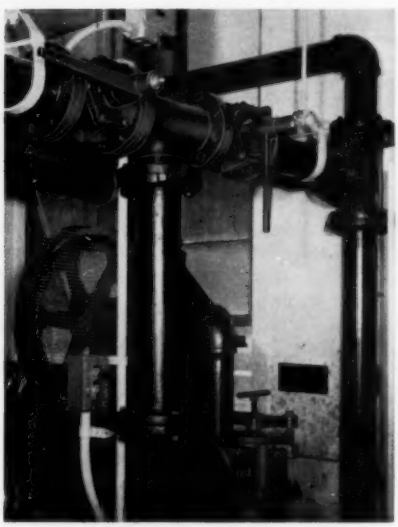
Philip R. Hirsh has been elected executive vice-president in charge of sales, production, and engineering for Lock Joint Pipe Co., East Orange, N.J.

Preston Pew has retired as manager of municipal sales for Infilco Inc., Tucson, Ariz., after 31 years with the company. He will be retained as a part-time consultant. Mr. Pew's successor is George W. Paulette, formerly district and field engineer with Infilco.

John W. Barrington, of Valparaiso, Ind., has been named sales representative for Neptune Meter. Co. in northern Illinois and northern Indiana. Mr. Barrington was previously in the inspection division of the Gary-Hobart Water Corp., Gary, Ind.

A. W. Lewis has retired after 40 years with US Pipe & Foundry Co., Birmingham, Ala. His successor as Cleveland sales agent is Timothy J. O'Shaughnessy, formerly with the company's Chicago sales office.

T. E. Woodruff, manager, Pump Sales Div., Fairbanks, Morse & Co., Kansas City, Kan., died Feb. 26, 1956, in Chicago. An employee of Fairbanks, Morse since 1912, he had been located in Kansas City for the past several years. Mr. Woodruff was very well known in the pump industry and was active on many committees. He served as an officer of the Hydraulics Society of America and the Turbine Pump Manufacturers Assn., and represented his company in AWWA.



NO LEAKAGE

The resilient-faced plug of a DeZurik Valve closes dead-tight on any line despite sand, silt, and scale in the flow.

NO LUBRICATION

Exclusive eccentric action guarantees easy operation . . . without binding, without sticking, without constant lube maintenance. DeZurik Valves open wide or close tight with an easy quarter-turn of the lever.

Get the complete details on DeZurik Valves. Representatives in all principal cities or write

DeZURIK SHOWER COMPANY
SARTELL, MINNESOTA

DELIVERING
WATER CHEAPER

Engineered and built by the city of Syracuse, N. Y., this 38.7″ Dresser-Coupled steel water supply line was backfilled immediately after each 30′ length was joined, getting streets back to work fast, practically eliminating the problem of trench cave-ins.

Too Quick for Cave-ins!

Dresser-Coupled steel line permits backfilling without delay

Whenever conditions demand immediate backfill, steel pipe and Dresser Couplings make it surer, safer to comply.

On this Syracuse water supply job, for example, the cave-in hazard of unstable sandy loam was heightened by heavy traffic nearby. The problem was solved by immediate backfilling, a standard Syracuse practice on all Dresser-Coupled water lines, where leaving trenches open for line test during construction is considered unnecessary.

Proved in thousands of installations, these factory-tested couplings give 100% bottle-tight joints every time. Their resilient rubber gaskets absorb vibration and pipe-transmitted stresses . . . assure no-leak safety for the life of the line.

Dresser Couplings and steel pipe provide trouble-free lines that always *deliver water cheaper.*

Wherever water flows, steel pipes it best. Always put steel pipe and Dresser Couplings in your specifications. Dresser Manufacturing Division, Bradford, Pa. Sales offices in: New York, Philadelphia, Chicago, South San Francisco, Houston, Denver, Toronto, Calgary.

ONE OF THE DRESSER INDUSTRIES

NEW MEMBERS

Applications received Apr. 1–30, 1956

Allen, Byron E., Utilities Supt., 112 Ballard, Box 547, Haysville, Kan. (Apr. '56) *MPD*

Anderson, William G., Owner, Anderson Constr. Co., Box 788, Abilene, Tex. (Apr. '56) *R*

Andrews, A. I., Div. Mgr., Wallace & Tiernan Inc., Derby Rd. & Turnbull Ave., Havertown, Pa. (Apr. '56)

Andrews, Norman E., Asst. Gen. Mgr., Water Works, 374 W. Santa Clara St., San Jose, Calif. (Apr. '56) *M*

Aubery, Melville W., Assoc. Civ. Engr., Water Dept. 903 Civic Center, San Diego 1, Calif. (Apr. '56) *RD*

Baer, George Alan, Asst. Dist. Mgr., Valve Div., S. Morgan Smith Co., 20 N. Wacker Dr., Chicago 6, Ill. (Apr. '56) *P*

Barker, Charles L., Prof., Dept. of Civ. Eng., State College of Washington, Pullman, Wash. (Apr. '56) *RD*

Barry, Carl A., Pres. & Treas., Paul E. Barry, Inc., Richland, Pa. (Apr. '56) *D*

Bennett, James B., City Engr., City Hall Annex, Shawnee, Okla. (Apr. '56) *MD*

Bertram, Albert E., Asst. San. Engr., Div. of Indian Health, US Public Health Service, 627—2nd Ave., Havre, Mont. (Apr. '56) *MRPD*

Boyles, Arthur F., Sr. Civ. Engr., Bureau of Water Supply, Munic. Office Bldg., Baltimore 2, Md. (Apr. 56) *MRD*

Brewster, Frank M., Jr., Pres., Belmont Quadrangle Drilling Corp., Box 373, Bradford, Pa. (Apr. '56) *P*

Briscoe, Conway B., Director of Public Utilities, Rm. 311 City Hall, St. Louis, Mo. (Apr. '56)

Brooks, Sam F., Jr., Mfer.'s Agent, Power Plant Efficiency Co., 901 E. Maryland, Indianapolis 6, Ind. (Apr. '56)

Brown, Howard, Supt., Merchantville-Pennsauken Water Com., 13 W. Maple Ave., Merchantville 8, N.J. (Apr. '56)

Brown, James P., Pump Inspector, Water Dept., 1710 San Angelo, San Antonio, Tex. (Apr. '56) *MP*

Brown, Sam C., Sales, Darling Valve & Mfg. Co., 1701 N. 6th St., Monroe, La. (Apr. '56)

Buck Hill Water Co., C. M. Reese, Supt., Buck Hill Falls, Pa. (Corp. M. Apr. '56) *MR*

Bucyrus, City of, Eugene Rockwell, Supt., Water Dept., Bucyrus, Ohio (Munic. Sv. Sub. Apr. '56)

Bullard, James W., Water Supt., Nueces County Water Control & Improvement Dist. No. 2, Rte. 4, Box 175, Flour Bluff, Corpus Christi, Tex. (Apr. '56) *M*

Burka, John M., Engr., Fountain City San. Dist., 104 Essary Rd., Knoxville 18, Tenn. (Apr. '56) *MRP*

Bushby, Merritt, City Engr., Waverly, Iowa (Apr. '56) *MRPD*

Cameron, William Edgar, Jr., City Engr. & Director of Public Works, City Hall, Sanger, Calif. (Apr. '56) *M*

Carlson, Dale A., Instructor of Civ. Eng., 121 More Hall, Univ. of Washington, Seattle 5, Wash. (Apr. '56) *D*

Case, Harry E., Sales Engr., Dravo Corp., Dravo Bldg., Pittsburgh 22, Pa. (Apr. '56) *PD*

Christian, Earl D., Dist. San. Engr., State Health Dept., Little Rock, Ark. (Apr. '56) *MRPD*

Clark, Charles J., Supt. of Production, Water Dept., Beaumont, Tex. (Apr. '56) *MRP*

Coutermarsh, Ernest R., Chairman, Water Com., 5 West St., Lebanon, N.H. (Apr. '56) *M*

Crabtree, Henry G., Public Relations, Buck, Seifert & Jost, 112 E. 19th St., New York 3, N.Y. (Apr. '56) *R*

D'Alessio, Sabato P., Well Drilling Contractor, Garden State Well & Pump Co., 290 Oliver St., Newark 5, N.J. (Jan. '56)

Davis, Arvin J. D., Plant Operator, Munic. Water System, 1316 Perry St., Helena, Ark. (Apr. '56) *MPD*

Doanldes, Peter J., Exec. Vice-Pres., Vacuum Concrete Inc., 4210 Sansom St., Philadelphia 4, Pa. (Apr. '56) *PD*

Donovan, Ernest, Supt. of Water, Yorktown, Ind. (Apr. '56) *MPD*

Dorman, Albert A., Civ. Engr., 128 E. 8th St., Hanford, Calif. (Apr. '56) *MPD*

Du Bois, Richard E., Engr., Glace & Glace, Inc., 1001 N. Front St., Harrisburg, Pa. (Apr. '56) *RPD*

Elias, George A., Regional San. Engr., State Dept. of Health, 915 Corinthian Ave., Philadelphia 30, Pa. (Apr. '56) *MRP*

El Paso Water Co., Inc., Eugene W. Godwin, Supt., 215 N. Baltimore, Box 727, El Paso (Derby), Kan. (Corp. M. Apr. '56) *MRD*

Erickson, Harold J., City Engr., City Hall, Wausau, Wis. (Apr. '56) *RD*

Fagen, Elwood, Water Supt., Redwood Falls, Minn. (Apr. '56) *MD*

Fletcher, Laird C., Supt., Water & Light, Natchitoches, La. (Apr. '56) *MD*

Friedlander, Robert N., Sales Engr., American Premaberg Co., Inc., 36 W. 40th St., New York 18, N.Y. (Apr. '56) *P*

Gallaher, Arden, Sales Repr., Collar & Co., 2818 Tauormee Ave., Kansas City, Kan. (Apr. '56) *MD*

Gauthier, E. A., Transite Pipe Specialist, Canadian Johns-Manville Co. Ltd., 1062 Sun Life Bldg., Montreal, Que. (Apr. '56) *D*

Godwin, Eugene W.; *see* El Paso (Kan.) Water Co.

Gray, Glenn C., Partner, Larkin & Assocs., 19 E. Gregory Bldg., Kansas City 14, Mo. (Apr. '56) *PD*

Guenther, Roland W., Operator, Water Works, Rte. 2, Box 10, Sault Ste. Marie, Mich. (Apr. '56) *P*

Hadden, John M., III, Asst. Supt., Consolidated Mutual Water Co., 10095 W. Colfax Ave., Lakewood, Colo. (Apr. '56) *PD*

(Continued on page 84 P&R)

Filter Sand and Gravel

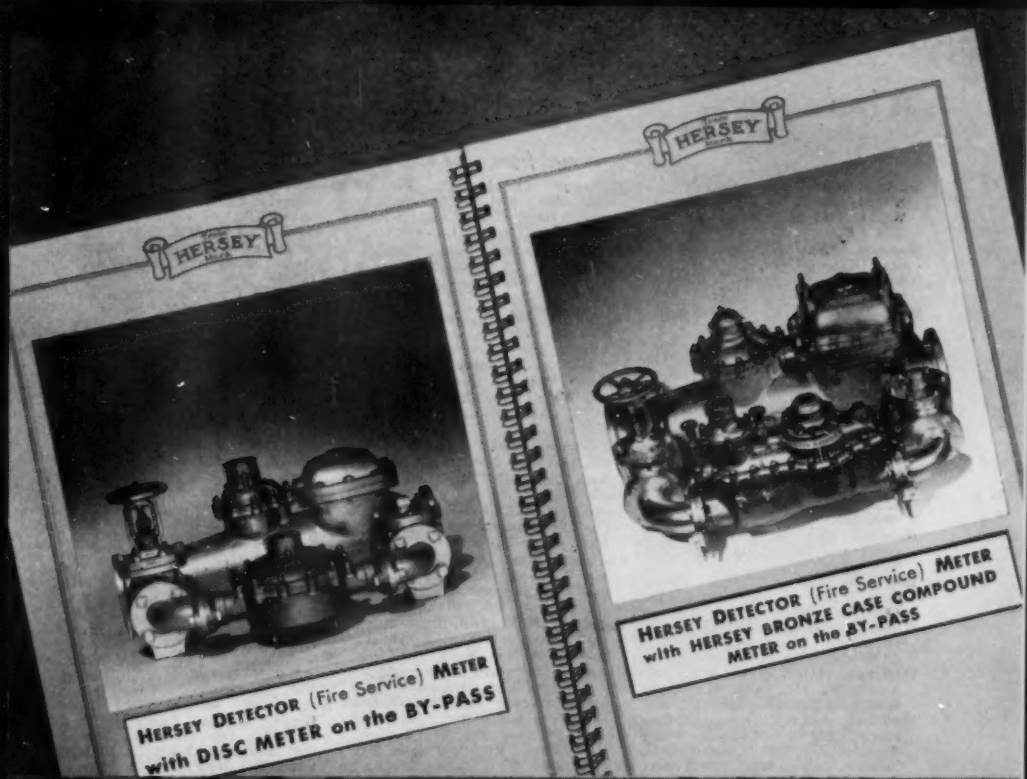
Well Washed and Carefully Graded to Any Specification.

Prompt Shipment in Bulk or in Bags of 100 lb. Each

Inquiries Solicited

NORTHERN GRAVEL COMPANY

P. O. Box 307 **Muscatine, Iowa**


HERSEY
HERSEY DETECTOR (Fire Service) METER with DISC METER on the BY-PASS
HERSEY
HERSEY DETECTOR (Fire Service) METER with HERSEY BRONZE CASE COMPOUND METER on the BY-PASS

HERSEY DETECTOR (Fire Service) METERS

Listed as standard under the re-examination service of Underwriters' Laboratories, Inc. and approved by Factory Mutual Laboratories for use in Factory Mutual insured properties, also listed by Underwriters' Laboratories of Canada.

HERSEY MANUFACTURING COMPANY

SOUTH BOSTON, MASS.

BRANCH OFFICES: NEW YORK — PORTLAND, ORE. — PHILADELPHIA — ATLANTA — DALLAS — CHICAGO
SAN FRANCISCO — LOS ANGELES

(*Continued from page 82 P&R*)

Hall, Robert Lyman, Civ. Engr., Alvord, Burdick & Howson, 20 N. Wacker Dr., Chicago 6, Ill. (Apr. '56) *RPD*

Hanson, Ross A., Assoc. Engr., State Water Survey, 605 E. Springfield Ave., Champaign, Ill. (Apr. '56) *MR*

Harper, John M.; *see* Murphy Ranch Mutual Water Co.

Haughwout, Richard F., Asst. Supt., Roslyn Water Dist., 1378 Northern Blvd., Roslyn, N.Y. (Apr. '56) *D*

Haydon, James E., Chemist, Munic. Authority of Westmorland County, 230 S. Pennsylvania Ave., Greensburg, Pa. (Apr. '56) *P*

Head, Frank M., Foreman, Water Dept., Montana Power Co., E. Broadway, Missoula, Mont. (Apr. '56) *RPD*

Helens, Roy J., Supt., Water Dept., Box 121, Philip, S.D. (Apr. '56) *RPD*

Hillegass, Lloyd B., Supt., Pennsburg Water Co., Pennsburg, Pa. (Apr. '56) *MD*

Hilton, George, Water Plant Operator, Water Works, Malvern, Ark. (Apr. '56) *PD*

Hoffman, John, Mgr., Apple Valley Water Co., Box 112 Dabel Sta., Dayton, Ohio (Apr. '56) *MD*

Hoffman, John F., Engr., US Geological Survey, Ground Water Branch, 230 Old Country Rd., Mineola, N.Y. (Apr. '56) *R*

Holdrege, Charles F., Asst. to Gen. Mgr., Metropolitan Utilities Dist., 18th & Harney Sts., Omaha, Neb. (Apr. '56) *MD*

Horner, W. W., Partner, Horner & Shifrin, 803 Shell Bldg., 1221 Locust St., St. Louis 3, Mo. (Apr. '56) *RP*

Hubbs, D. E. H., Service Repr., National Silicates Ltd., Box 69, Toronto 14, Ont. (Apr. '56)

Hurley, A. Thomas, Director of Public Relations, Consolidated Mutual Water Co., 10095 W. Colfax Ave., Lakewood, Colo. (Apr. '56) *M*

Ingraham, Carl M., Sales, Grinnell Co. Inc., North Kansas City, Kan. (Apr. '56) *M*

Jackson, Calvin A., Chief Operator, Kansas City Suburban Water Co., 5916 Dearborn St., Mission, Kan. (Apr. '56) *P*

Jackson, Hugh P., Water & Sewage Engr., Hercules Powder Co., Sunflower Ordnance Works, Lawrence, Kan. (Apr. '56) *MRP*

Johnson, J. Leland, Distr. Engr., Water Dept., City Hall, Topeka, Kan. (Apr. '56) *M*

Johnson, Norman F., Asst. Water & Sewage Engr., Hercules Powder Co., Sunflower Ordnance Works, Lawrence, Kan. (Apr. '56) *MRP*

Jolly, Charles W., Water Supt., Distr. Dept., Rte. 3, Teague, Tex. (Apr. '56) *M*

Jones, Gay A., Supt., Water & Sewer Dept., Shawnee, Okla. (Apr. '56) *MRP*

Kaercher, Leonard, Supt., Univ. of Minnesota, Rosemount Research Center, Rosemount, Minn. (Apr. '56) *M*

Kay, W. P., Plant Supt., Lake Providence, La. (Apr. '56)

Keenan, H. J., Sales Engr., Hume Industries (Far East) Ltd., GPO Box 297, Singapore, Malaya (Apr. '56) *D*

Keir, James MacLaren, Asst. Gen. Supt., Water Operations Dept., Metropolitan Utilities Dist., 18th & Harney Sts., Omaha 2, Neb. (Apr.. '56) *MR*

Kendall, Thurlow, Civ. Engr., Dept. of Water & Power, Box 3669 Terminal Annex, Los Angeles 54, Calif. (Apr. '56) *RD*

Kern, Fred J., Dist. Mgr., Fischer & Porter Co., 2103 W. 42nd St., Kansas City, Kan. (Apr. '56) *P*

Klever, Charles F., Supt., Water Operations, Metropolitan Utilities Dist., Florence Pumping Sta., Omaha 12, Neb. (Apr. '56) *PD*

Klingler, Alfred F.; *see* Shelby (Mont.)

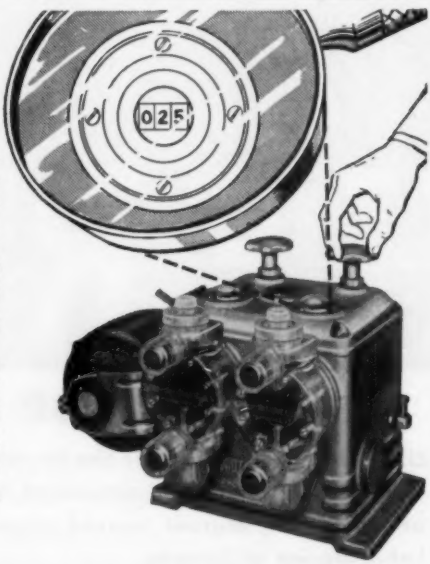
Klockner, Lewis W., Jr., Supt., Water Works, Box 528, Trenton, N.J. (Apr. '56) *MPD*

Kranaskas, Anthony J., Assoc. Director & Chief Engr., Health & Sanitation Div., ICA–IAA, American Embassy, Bogota, Colombia (Apr. '56) *MRPD*

(*Continued on page 86 P&R*)

SET THE FEED YOU NEED!

PROPORTIONEERS, INC. Chem-O-Feeder® allows you to adjust pumping capacity while unit is running . . . for each pumping head independently. Here's maximum convenience and control in your water conditioning operations. Three models available . . . simplex, duplex, triplex, for rates from 0.2 to 57 GPH against pressures to 125 psig . . . all with PROPORTIONEERS-perfected "see-thru" head . . . for double check on pumping action. For Bulletin 1225-2 write to **PROPORTIONEERS, INC.,** 365 Harris Avenue, Providence 1, R. I. . . . division of



B-I-F INDUSTRIES
PROVIDENCE, RHODE ISLAND
METERS FEEDERS CONTROLS

BRING ON YOUR RIVERS!

CLOW RIVER-CROSSING CAST IRON PIPE TAKES 'EM "IN STRIDE"!

EASY TO LAY. As easy to make up as a standard flanged joint. Lower labor installation cost because of ease of joint make-up and longer laying lengths.

ONLY A RATCHET WRENCH NEEDED. No split parts. Fewer parts—each joint consisting of one complete pipe, one solid follower ring, one solid ring gasket, bolts and nuts.

FULL 15° TURNING DEFLECTION with absolutely no reduction in the full internal opening area—therefore, no abnormal pressure-drops at deflected joints. Deflection stresses evenly distributed among all the bolts.

LONGER LAYING LENGTHS—approximately 18′6″—faster installation, lower costs. However, lengths may be varied to suit conditions. For example: 6 foot, 12 foot or other special lengths may be advisable to suit required curvature.

Mail coupon for complete information on Clow Ball-and-Socket River-Crossing Pipe. No obligation, naturally.

JAMES B. CLOW & SONS
201-299 North Talman Avenue
Chicago 80, Illinois

Subsidiaries:
Eddy Valve Co., Waterford, N.Y.
Iowa Valve Co., Oskaloosa, Iowa

JAMES B. CLOW & SONS
201-299 North Talman Avenue
Chicago 80, Illinois

Please send me, without obligation, details and specifications of Clow Ball-and-Socket River-Crossing Pipe.

Company_____
Street Address_____
City_____ Zone____ State____
Individual's Name_____
Position_____

(Continued from page 84 P&R)

Laferla, Joseph P., Engr., Metropolitan Utilities Dist., 18th & Harney Sts., Omaha 2, Neb. (Apr. '56) *PD*

Longhurst, Stanley A., Asst. Supt., Westchester Joint Water Works No. 1, 129 Halstead Ave., Mamaroneck, N.Y. (Apr. '56) *MRPD*

Lord, Dennis, Chief Engr., Ashtabula Water Works Co., Ashtabula, Ohio (Apr. '56) *MP*

Lowry, Eldridge B., Engr., Dept. of Water & Power, Box 3669 Terminal Annex, Los Angeles 54, Calif. (Apr. '56) *M*

Madden, John, Jr., Sales Repr., US Pipe & Foundry Co., 71 Broadway, New York, N.Y. (Apr. '56) *D*

Maddock, William B., Sales Engr., Johns-Manville Sales Corp., 777 Thomas St., Seattle 9, Wash. (Apr. '56) *D*

Maree, William Whit, Asst. Plumbing Inspector, State Board of Health, Div. of Plumbing, 1116 Battery St., Little Rock, Ark. (Apr. '56) *MD*

Mattison, Ralph W., Utilities Foreman, Sanitation Branch, Stead Air Force Base, Reno, Nev. (Apr. '56) *MPD*

McIntosh, Benjamin K., Chief Operator, Dept. of National Defence, Camp Wainwright, Wainwright, Alta. (Apr. '56)

Mead, J. E., Sales, Dresser Mfg. Div., 1514 Montclair Pl., Ann Arbor, Mich. (Apr. '56) *D*

Mima, James J., Asst. Director, Water Dept., City Hall, 105 E. Queen St., Inglewood, Calif. (Apr. '56) *M*

Moir, W. Stewart, Dist. Mgr., Wallace & Tiernan, Ltd., Box 54, Toronto 13, Ont. (Jan. '56)

Moran, Willard B., City Mgr., Box 1002, Shawnee, Okla. (Apr. '56) *MR*

Morgan, Leigh R., City Engr., Box 231, Havre, Mont. (Apr. '56) *M*

Murphy Ranch Mutual Water Co., John M. Harper, Asst. Mgr., 15305 E. Carretera Dr., Whittier, Calif. (Corp. M. Apr. '56) *M*

Osborne, C. A., Supt., Water Works, Tullahoma, Tenn. (Apr. '56) *M*

Parker, Ivan G., Engr., Water Dept., City Hall, Santa Cruz, Calif. (Apr. '56) *MRPD*

Parker, James Ralph, Salesman, Ford Meter Box Co., Inc., 312 Peyton Ave., Haddonfield, N.J. (Apr. 56) *D*

Puddy, Harold M., Supt., Water Works, 211—2nd St., Box 27, Hood River, Ore. (Apr. '56) *M*

Radziul, Joseph V., Civ. Engr., Water Dept., Rm. 1121, City Hall Annex, Philadelphia, Pa. (Apr. '56) *MD*

Reed, Philip A., Water Chem. Engr., South Dist. Filtration Plant, 3300 E. Cheltenham Pl., Chicago 49, Ill. (Apr. '56) *MP*

Reese, C. M.; *see* Buck Hill Water Co.

Roberts, Bruce, Asst. Gen. Mgr., Wilson & Co., Box 28, Salina, Kan. (Apr. '56) *MRPD*

Rockwell, Eugene; *see* Bucyrus (Ohio)

Rodgers, James L., Jr., Design Engr., American Water Works Service Co., 3 Penn Center Plaza, Philadelphia 2, Pa. (Apr. '56) *RP*

Sager, John R., Asst. Supt., Water & Sewage, 2310—2nd St., Cuyahoga Falls, Ohio (Apr. '56) *MRPD*

Schmidt, Robert H., Facilities Engr., Area Development Committee, 805 First National Tower, Akron 8, Ohio (Apr. '56) *RD*

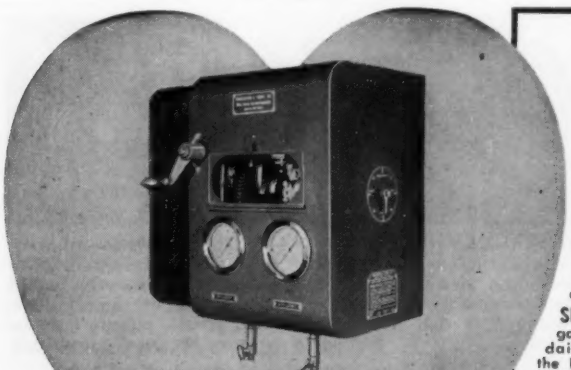
Schowengerdt, Henry A., Utilities Engr., Hercules Powder Co., Lawrence, Kan. (Apr. '56)

Scott, Murray C., Sales Engr., J. W. Eshelman Co., 1812—28th Ave. S., Birmingham, Ala. (Apr. '56) *P*

Seabloom, Robert W., Student, Univ. of Washington, 3619—50th Ave. S.W., Seattle 16, Wash. (Jr. M. Apr. '56) *RP*

Shea, Edward W., Gen. Mgr., Water Distr. System, Carrollton, Ky. (Apr. '56) *MPD*

(Continued on page 88 P&R)



THE HEART OF ANY GOOD WATER SOFTENER OR FILTER

HUNGERFORD & TERRY, INC.
CLAYTON 5, N. J.

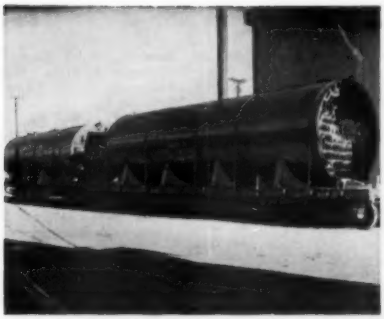
THE H & T POPPET TYPE MULTIPORT VALVE

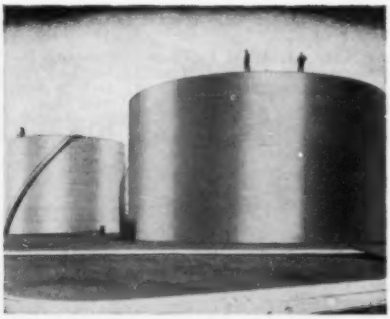
A masterpiece of workmanship and operating simplicity. Your choice of manual, semi-automatic, or fully automatic.

SERVICE — Many millions of gallons of water are treated daily by equipment using the H & T poppet valve. Over 1,000 are now in use and the number is rapidly increasing. Many of the original valves are now in use for over 10 years.

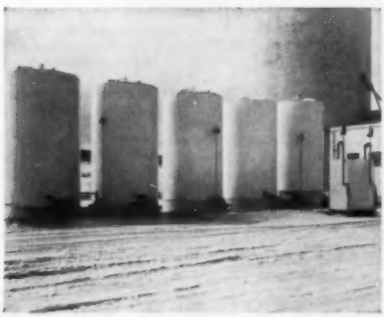
MODERNIZING OLD SOFTENERS AND FILTERS — If your equipment is too good to discard, yet too old to be efficient or too complicated to operate and control, these units can very often be equipped with H & T poppet type multiport valves — and be made into attractive and efficient water treating units.

Write for free information bulletin





Here's the answer



to a lot of tank problems

American has been building tanks of many types, pressure vessels and storage reservoirs for a third of a century. This great store of experience in the design, fabrication and field erection of these products has resulted in carefully engineered custom fabricated units at the lowest possible cost. Facilities, experience and personnel have made American outstanding in the field. Job-timed delivery eliminates costly construction delay.

You'll find it easy, profitable and pleasant to do business with American.

Write or phone to have an American sales engineer help you plan your next job.

American
PIPE AND CONSTRUCTION CO.
NORTHWEST DIVISION
518 N. E. Columbia Blvd. (Near Union Ave.)
Portland 11, Oregon UKiah 2531
Los Angeles · Hayward · San Diego

(Continued from page 86 P&R)

Shelby, City of, Alfred F. Klingler, Mayor, Shelby, Mont. (Munic. Sv. Sub. Apr. '56) *MD*

Smit, Raymond J., Civ. Engr., Ayres, Lewis, Norris & May, 500 Wolverine Bldg., Ann Arbor, Mich. (Apr. '56) *PD*

Smith, Earl A., Sr., Sales Engr., Badger Meter Mfg. Co., 2745 S. Greeley St., Milwaukee 7, Wis. (Apr. '56) *D*

Smith, Earl D., Jr., Water Meter Salesman, Badger Meter Mfg. Co., 2357 N. 30th St., Milwaukee, Wis. (Apr. '56) *D*

Smith, William Harold, Director, Public Utilities, Box 119, Alice, Tex. (Apr. '56) *MR*

Sortor, Charles H., Mgr., Laval Underground Surveys, 2216 E. McKinley Ave., Fresno 3, Calif. (Apr. '56) *R*

Speer, George M., Supt., Water & Elec. Plant, Abbeville, S.C. (Apr. '56) *MPD*

Springs, Worth A., Salesman, Grinnell Co., 1431 W. Morehead St., Charlotte, N.C. (Apr. '56)

Strickland, James M., Jr., Engr., Waterworks Com., 6100 Virginia Ave., Newport News, Va. (Apr. '56) *MRP*

Suhajcik, Stephen, Comr., Utilities Fiscal Control, Dept. of Public Utilities, Rm. 112 City Hall, Cleveland, Ohio (Apr. '56) *M*

Swanson, N. George, Supt. of Maint., Metropolitan Utilities Dist., 18th & Harney Sts., Omaha 2, Neb. (Apr. '56) *MD*

Taft, Walter D., Jr., Sales Engr., Dravo Corp., Suburban Sta. Bldg., Philadelphia 3, Pa. (Apr. '56) *PD*

Taylor, Bette B., Pres., Water Works Supply Corp., Johnstown, N.Y. (Apr. '56) *D*

Than, Hoang-Ngoc, Civ. Engr., Ministry of Public Works of Vietnam (Saigon), Box 2564, Boulevard Sta., Norman, Okla. (Apr. '56) *MRP*

Tindal, Robert T., Assoc. Prof. of Civ. Eng., Univ. of Alabama, University, Ala. (Apr. '56) *RPD*

Trani, Samuel E., San. Engr., State Board of Health, Little Rock, Ark. (Apr. '56) *P*

Treuil, Gordon, Supt., Belle Chasse Water Works, Rte. 5, Box 401C, New Orleans 14, La. (Apr. '56)

Troxel, L. W., Foreman, Water Dept., City Hall, Corvallis, Ore. (Apr. '56) *M*

Usry, E. W., Supt., Water & Sewage, Troup, Tex. (Apr. '56)

Wabash Water Corp., 41 W. Canal St., Wabash, Ind. (Corp. M. Apr. '56)

Wagerson, Stanley J., Supt., Div. of Water Supply, Dearborn, Mich. (Jan. '56) *MD*

Weigand, Herman, Chemist, Water Dept., Leavenworth, Kan. (Apr. '56) *P*

Wells, Bon L., Sales Engr., Wintroath Pumps, 1100 S. Meridian Ave., Alhambra, Calif. (Apr. '56) *RD*

West, Paul M., City Engr., Box 3466, Odessa, Tex. (Apr. '56)

Weston, Roy A., Industrial Sales Repr., Empire Brass Mfg. Co., 20 Jackson St., Hamilton, Ont. (Apr. '56)

White, Gale B., Research Fellow & Student, Eng. Experiment Sta., Univ. of Washington, 715 Harrison Ave., Seattle 9, Wash. (Jr. M. Apr. '56) *P*

Whiting, Kenneth W., Supt., Water Works, Cotton Plant, Ark. (Apr. '56) *MRPD*

Wiguszyn, Leon, Engr., Canadian Waterworks & Ozone Co., Ltd., 4250 Marcil Ave., Apt. 16, Montreal 28, Que. (Apr. '56)

Willey, Benjamin F., Director of Tech. Information, Elgin Softener Corp., 134 N. Grove Ave., Elgin, Ill. (Apr. '56) *RP*

Wolfe, Deldert, Supt., Bethel Water Dist., 2485 Roosevelt Blvd., Eugene, Ore. (Apr. '56) *M*

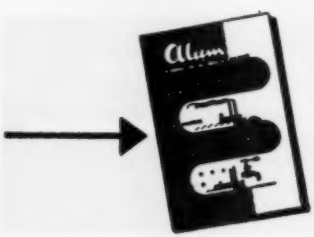
Zervakos, Straty, Designing Engr., Washington Suburban San. Com., 4209 Oglethorpe St., Hyattsville, Md. (Apr. '56) *D*

Zumstein, Robert H., Secy.-Treas., Civil Engineers, Inc., 15934 W. McNichols Rd., Detroit 35, Mich. (Apr. '56) *PD*

Depend on Cyanamid's ALUM for 6 good reasons

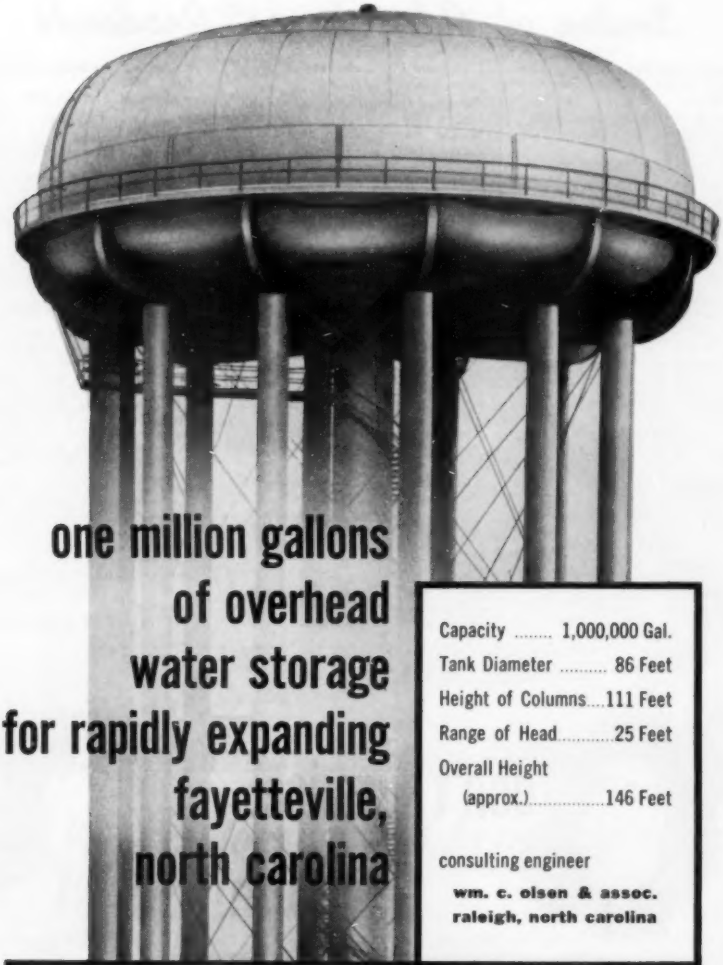
1. It feeds uniformly, without trouble, in solid or liquid form.
2. It has a wide pH range for effective coagulation.
3. It forms floc rapidly.
4. It gives maximum adsorption of suspended and colloidal impurities.
5. It causes minimum corrosion of feeding equipment.
6. It is available in granular form or in the new easy-to-use liquid form.

For a copy of "Alum—Commercial Aluminum Sulfate," please send us your name and title on company stationery—and would you also mention where you saw this offer?



AMERICAN Cyanamid COMPANY
Heavy Chemicals Department
30 Rockefeller Plaza, New York 20, N.Y.

In Canada: North American Cyanamid Limited, Toronto & Montreal



one million gallons of overhead water storage for rapidly expanding fayetteville, north carolina

Capacity ..... 1,000,000 Gal.
Tank Diameter ..... 86 Feet
Height of Columns....111 Feet
Range of Head.....25 Feet
Overall Height (approx.).....146 Feet

consulting engineer
wm. c. olsen & assoc.
raleigh, north carolina

Steel Standpipes, Steel Reservoirs, Elevated Water Tanks, Water Spheres, Filtration and Purification Units for General Water Supply & Fire Protection Systems

Write for Catalog H_2O

HAMMOND IRON WORKS

WARREN and BRISTOL, PA. • PROVO, UTAH • CASPER, WYO. • BIRMINGHAM, ALA.

sales offices: new york 20 • boston 10 • arlington, va. 9 • cincinnati 2 chicago 3 • los angeles 57 • greenville, s. c. • sapulpa, okla. buenos aires • lima • mexico, d.f. • port-au-prince • cairo

Index of Advertisers' Products

Activated Carbon:
Industrial Chemical Sales Div.
Permutit Co.

Activated Silica Generators:
Omega Machine Co. (Div., B-I-F Industries)
Wallace & Tiernan Inc.

Aerators (Air Diffusers):
American Well Works
Carborundum Co.
General Filter Co.
Infilco Inc.
Permutit Co.
Walker Process Equipment, Inc.

Air Compressors:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.
Morse Bros. Mchy. Co.

Alum (Sulfate of Alumina):
American Cyanamid Co., Heavy Chemicals Dept.
General Chemical Div.

Ammonia, Anhydrous:
General Chemical Div.
John Wiley Jones Co.

Ammoniators:
Fischer & Porter Co.
Proportioneers, Inc. (Div., B-I-F Industries)
Wallace & Tiernan Co., Inc.

Brass Goods:
American Brass Co.
M. Greenberg's Sons
Hays Mfg. Co.
Mueller Co.

Calcium Hypochlorite:
John Wiley Jones Co.

Carbon Dioxide Generators:
Infilco Inc.
Walker Process Equipment, Inc.

Cathodic Protection:
Electro Rust-Proofing Corp.
Harco Corp.

Cement, Portland:
Monolith Portland Midwest Co.

Cement Mortar Lining:
Centriline Corp.

Chemical Feed Apparatus:
Cochrane Corp.
Fischer & Porter Co.
Graver Water Conditioning Co.
Infilco Inc.
F. B. Leopold Co.
Omega Machine Co. (Div., B-I-F Industries)
Permutit Co.
Proportioneers, Inc. (Div., B-I-F Industries)
Ross Valve Mfg. Co.
Simplex Valve & Meter Co.
Wallace & Tiernan Inc.

Chemists and Engineers:
(See Professional Services)

Chlorination Equipment:
Builders-Providence, Inc. (Div., B-I-F Industries)
Everson Mfg. Corp.
Fischer & Porter Co.
Proportioneers, Inc. (Div., B-I-F Industries)
Wallace & Tiernan Inc.

Chlorine Comparators:
Klett Mfg. Co
Wallace & Tiernan Inc.

Chlorine, Liquid:
John Wiley Jones Co.
Wallace & Tiernan Inc.

Clamps and Sleeves, Pipe:
James B. Clow & Sons
Dresser Mfg. Div.
M. Greenberg's Sons
Mueller Co.
Rensselaer Valve Co.
Skinner, M. B., Co.
A. P. Smith Mfg. Co.
Smith-Blair, Inc.
Trinity Valley Iron & Steel Co.

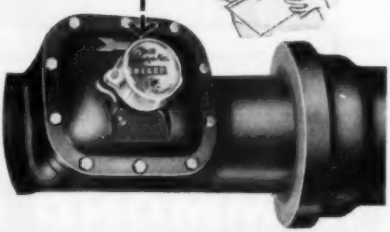
Clamps, Bell Joint:
James B. Clow & Sons
Dresser Mfg. Div.
Skinner, M. B., Co.

Clamps, Pipe Repair:
James B. Clow & Sons
Dresser Mfg. Div.
Skinner, M. B., Co.
Trinity Valley Iron & Steel Co.

Clarifiers:
American Well Works
Chain Belt Co.
Cochrane Corp.
Dorr-Oliver Inc.
General Filter Co.
Graver Water Conditioning Co.
Infilco Inc.
Permutit Co.
Walker Process Equipment, Inc.

don't surmise...

totalize!



Builders-Providence PROPELOFLO® is a direct-reading, propeller-type meter designed for main line totalizing of water consumption . . . available in 2 to 20 inch sizes . . . with flanged, bell and spigot, and threaded ends. Rated capacities range from 15 to 5800 gpm . . . accurate to within plus or minus 2% of actual flow. For complete information, write to **BUILDERS-PROVIDENCE, INC.,** 365 Harris Ave., Providence 1, R. I.

. . . division of

B-I-F INDUSTRIES

PROVIDENCE, RHODE ISLAND

B-I-F METERS FEEDERS CONTROLS

'Red Water' doesn't live here any more!

No more 'Red Water'—thanks to Threshold Treatment with Calgon*—that's the record in this typical community.

When Calgon treatment was started, 'Red Water' stopped, and now everyone is complimenting the water superintendent.

Calgon in very small amounts is effective against 'Red Water' because it not only stabilizes iron and manganese dissolved in water at its source, but it also prevents iron pickup from pipes.

Calgon stops lime scale, too, by forcing calcium carbonate and other scale-forming chemicals to stay in solution, even when the water is heated. Calgon is used in minute amounts, and the reduction of lime scale means important savings in keeping equipment and meters clean.

Call on Calgon for the economical solution to your specific problem. Many years of experience with water problems of all kinds in every part of the country are at your service.

*Calgon is the Registered Trade Mark of Calgon, Inc. for its glassy phosphate (sodium hexametaphosphate) products.

HAGAN

calgon, inc.

A Subsidiary of Hagan Corporation
Hagan Building • Pittsburgh 30, Pa.

Condensers:
Alco Products, Inc.
Allis-Chalmers Mfg. Co.
United States Pipe & Foundry Co.

Contractors, Water Supply:
Layne & Bowler, Inc.

Controllers, Liquid Level, Rate of Flow:
Builders-Providence, Inc. (Div., B-I-F Industries)
Fischer & Porter Co.
Foxboro Co.
General Filter Co.
Infilco Inc.
Minneapolis-Honeywell Regulator Co.
Simplex Valve & Meter Co.

Copper Sheets:
American Brass Co.

Copper Sulfate:
General Chemical Div.
Phelps Dodge Refining Corp.
Tennessee Corp.

Corrosion Control:
Alco Products, Inc.
Calgon, Inc.
Philadelphia Quartz Co.

Couplings, Flexible:
DeLaval Steam Turbine Co.
Dresser Mfg. Div.
Philadelphia Gear Works, Inc.

Diaphragms, Pump:
Dorr-Oliver Inc.
Morse Bros. Mchy. Co.
Southern Pipe & Casing Co.

Engines, Hydraulic:
Ross Valve Mfg. Co.

Engineers and Chemists:
(See Professional Services)

Feedwater Treatment:
Allis-Chalmers Mfg. Co.
Calgon, Inc.
Cochrane Corp.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
Infilco Inc.
Permutit Co.
Proportioneers, Inc. (Div., B-I-F Industries)

Ferric Sulfate:
Tennessee Corp.

Filter Materials:
Anthracite Equipment Corp.
Carborundum Co.
General Filter Co.
Infilco Inc.
Johns-Manville Corp.
Northern Gravel Co.
Permutit Co.
Carl Schleicher & Schuell Co.
Stuart Corp.

Filters, incl. Feedwater:
Cochrane Corp.
Dorr-Oliver Inc.
Graver Water Conditioning Co.
Infilco Inc.
Morse Bros. Mchy. Co.
Permutit Co.
Proportioneers, Inc. (Div., B-I-F Industries)
Roberts Filter Mfg. Co.
Ross Valve Mfg. Co.

Filters, Membrane (MF):
Millipore Filter Corp.
Carl Schleicher & Schuell Co.

Filtration Plant Equipment:
Builders-Providence, Inc. (Div., B-I-F Industries)
Chain Belt Co.
Cochrane Corp.
Filtration Equipment Corp.
General Filter Co.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
Infilco Inc.
F. B. Leopold Co.
Omega Machine Co. (Div., B-I-F Industries)
Permutit Co.
Roberts Filter Mfg. Co.
Stuart Corp.
Wallace & Tiernan Inc.

Fittings, Copper Pipe:
Dresser Mfg. Div.
M. Greenberg's Sons
Hays Mfg. Co.
Mueller Co.

Fittings, Tees, Ells, etc.:
Alco Products, Inc.
Cast Iron Pipe Research Assn.
James B. Clow & Sons
Crane Co.
Dresser Mfg. Div.
M & H Valve & Fittings Co.
Trinity Valley Iron & Steel Co.
United States Pipe & Foundry Co
R. D. Wood Co.

Flocculating Equipment:
Chain Belt Co.
Cochrane Corp.
Dorr-Oliver Inc.
General Filter Co.
Graver Water Conditioning Co.
Infilco Inc.
F. B. Leopold Co.
Permutit Co.
Stuart Corp.

Fluoride Chemicals:
American Agricultural Chemical Co.

Fluoride Feeders:
Fischer & Porter Co.
Omega Machine Co. (Div., B-I-F Industries)
Proportioneers, Inc. (Div., B-I-F Industries)
Wallace & Tiernan Co., Inc.

Furnaces:
Jos. G. Pollard Co., Inc.

Gages, Liquid Level:
Builders-Providence, Inc. (Div., B-I-F Industries)
Infilco Inc.
Minneapolis-Honeywell Regulator Co.
Simplex Valve & Meter Co.
Wallace & Tiernan Inc.

Gages, Loss of Head, Pressure & Vacuum, Rate of Flow, Sand Expansion:
Builders-Providence, Inc. (Div., B-I-F Industries)
Foxboro Co.
Infilco Inc.
Minneapolis-Honeywell Regulator Co.
Jos. G. Pollard Co., Inc.
Simplex Valve & Meter Co.
Wallace & Tiernan Inc.

Gasholders:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Hammond Iron Works
Pittsburgh-Des Moines Steel Co.

Gaskets, Rubber Packing:
James B. Clow & Sons
Johns-Manville Corp.

Gates, Shear and Sluice:
Armco Drainage & Metal Products, Inc.
Chapman Valve Mfg. Co.
James B. Clow & Sons
Morse Bros. Mchy. Co.
Mueller Co.
R. D. Wood Co.

Gears, Speed Reducing:
DeLaval Steam Turbine Co.
Philadelphia Gear Works, Inc.

Glass Standards—Colorimetric Analysis Equipment:
Klett Mfg. Co.
Wallace & Tiernan Inc.

Goosenecks (with or without Corporation Stops):
James B. Clow & Sons
Hays Mfg. Co.
Mueller Co.

Hydrants:
James B. Clow & Sons
Darling Valve & Mfg. Co.
M. Greenberg's Sons
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
A. P. Smith Mfg. Co.
Rensselaer Valve Co.
R. D. Wood Co.

Hydrogen Ion Equipment:
Wallace & Tiernan Inc.

Hypochlorite; see Calcium Hypochlorite; Sodium Hypochlorite

Ion Exchange Materials:
Allis-Chalmers Mfg. Co.
Cochrane Corp.
General Filter Co.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
Infilco Inc.
Permutit Co.
Roberts Filter Mfg. Co.

Iron, Pig:
Woodward Iron Co.

Iron Removal Plants:
American Well Works
Chain Belt Co.
Cochrane Corp.
General Filter Co.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
Infilco Inc.
Permutit Co.
Roberts Filter Mfg. Co.
Walker Process Equipment, Inc.

Jointing Materials:
Hydraulic Development Corp.
Johns-Manville Corp.
Keasbey & Mattison Co.
Leadite Co., Inc.

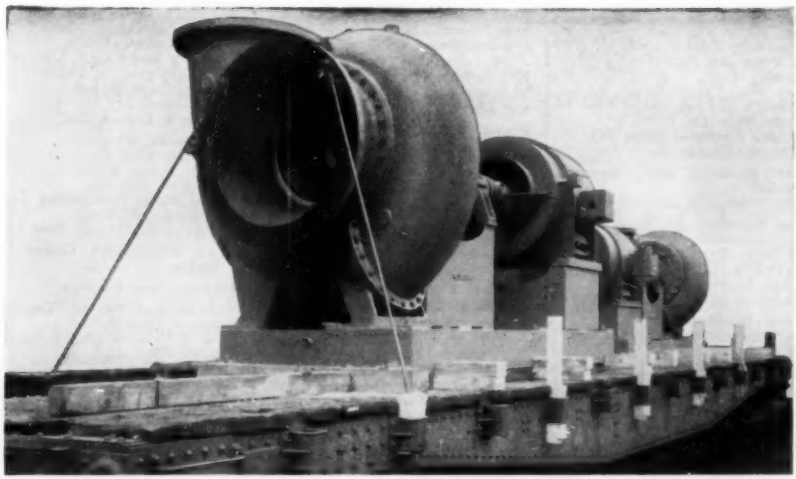
Joints, Mechanical, Pipe:
American Cast Iron Pipe Co.
Cast Iron Pipe Research Assn.
James B. Clow & Sons
Dresser Mfg. Div.
Trinity Valley Iron & Steel Co.
United States Pipe & Foundry Co.
R. D. Wood Co.

Leak Detectors:
Jos. G. Pollard Co., Inc.

Lime Slakers and Feeders:
Dorr-Oliver Inc.
General Filter Co.
Infilco Inc.
Omega Machine Co. (Div., B-I-F Industries)
Permutit Co.
Wallace & Tiernan Inc.

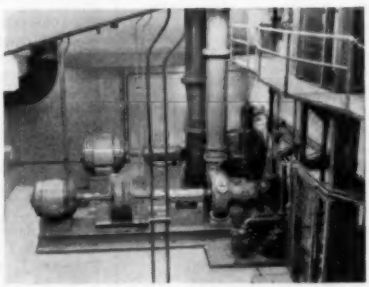
Magnetic Dipping Needles:
W. S. Darley & Co.

Meter Boxes:
Ford Meter Box Co.
Pittsburgh Equitable Meter Div.



THESE WHEELER-ECONOMY PUMPS HOLD CONSTANT LEVELS IN THE NEW TRICKLING FILTERS AT DALLAS' WHITE ROCK PLANT

Two of the Wheeler-Economy pumps installed in the White Rock Sewage Treatment Plant for Dallas, Texas are believed to be the largest ever operated through magnetic couplings. In order to maintain constant levels in the suction wells and grit channels, each of the two units driven through magnetic couplings are governed by an elaborate float level control. This helps the big Wheeler-Economy pumps to maintain level within predetermined 6" limitations. Total pumping capacity of the four Wheeler-Economy pumps installed at the White Rock Plant is 134 million gallons a day.



WHEELER-ECONOMY HORIZONTAL, MIXED FLOW RAW SEWAGE PUMPS AT INSTALLATION

Rely on Wheeler-Economy for help in complex pumping problems, dependable delivery and performance that lives up to promise.

Wheeler-Economy Pumps in Operation at Dallas' White Rock Plant

- 24" suction x 24" discharge variable speed pump driven through magnetic coupling by a 250 HP, 2300 volt horizontal electric motor. Capacity 20,000 gallons per minute at 40' total dynamic head.
- 24" x 20" variable speed pump, driven through magnetic coupling by 200 HP, 2300 volt motor. Capacity 13,000 GPM at 40' TDH.
- 42" x 36" constant speed pump, driven by 400 HP, 2300 volt motor. Capacity 40,000 GPM at 37' TDH.
- 24" x 20" constant speed pump, driven by 200 HP, 2300 volt motor. Capacity 20,000 GPM at 37' TDH.

WE525

WHEELER-ECONOMY PUMPS

ECONOMY PUMPS, INC. · DIVISION OF C. H. WHEELER MANUFACTURING CO.
19TH AND LEHIGH PHILADELPHIA 32, PA.

Meter Couplings and Yokes:
Badger Meter Mfg. Co.
Dresser Mfg. Div.
Ford Meter Box Co.
Hays Mfg. Co.
Hersey Mfg. Co.
Mueller Co.
Neptune Meter Co.
Pittsburgh Equitable Meter Div.
Worthington-Gamon Meter Co.

Meter Reading and Record Books:
Badger Meter Mfg. Co.

Meter Testers:
Badger Meter Mfg. Co.
Ford Meter Box Co.
Hersey Mfg. Co.
Neptune Meter Co.
Pittsburgh Equitable Meter Div.

Meters, Domestic:
Badger Meter Mfg. Co.
Buffalo Meter Co.
Hersey Mfg. Co.
Neptune Meter Co.
Pittsburgh Equitable Meter Div.
Well Machinery & Supply Co.
Worthington-Gamon Meter Co.

Meters, Filtration Plant, Pumping Station, Transmission Line:
Builders-Providence, Inc. (Div., B-I-F Industries)
Foster Eng. Co.
Infilco Inc.
Minneapolis-Honeywell Regulator Co.
Simplex Valve & Meter Co.

Meters, Industrial, Commercial:
Badger Meter Mfg. Co.
Buffalo Meter Co.
Builders-Providence, Inc. (Div., B-I-F Industries)
Fischer & Porter Co.
Hersey Mfg. Co.
Neptune Meter Co.
Pittsburgh Equitable Meter Div.
Simplex Valve & Meter Co.
Well Machinery & Supply Co.
Worthington-Gamon Meter Co.

Mixing Equipment:
Chain Belt Co.
General Filter Co.
Infilco Inc.
F. B. Leopold Co.

Paints:
Barrett Div.
Inertol Co., Inc.

Pipe, Asbestos-Cement:
Johns-Manville Corp.
Keasbey & Mattison Co.

Pipe, Brass:
American Brass Co.

Pipe, Cast Iron (and Fittings):
American Cast Iron Pipe Co.
Cast Iron Pipe Research Assn.
James B. Clow & Sons
Trinity Valley Iron & Steel Co.
United States Pipe & Foundry Co.
R. D. Wood Co.

Pipe, Cement Lined:
American Cast Iron Pipe Co.
Cast Iron Pipe Research Assn.
James B. Clow & Sons
United States Pipe & Foundry Co.
R. D. Wood Co.

Pipe, Concrete:
American Concrete Pressure Pipe Assn.
American Pipe & Construction Co.
Lock Joint Pipe Co.

Pipe, Copper:
American Brass Co.

Pipe, Steel:
Alco Products, Inc.
Armco Drainage & Metal Products, Inc.
Bethlehem Steel Co.

Pipe Cleaning Services:
National Water Main Cleaning Co.

Pipe Cleaning Tools and Equipment:
Flexible Inc.

Pipe Coatings and Linings:
Barrett Div.
Cast Iron Pipe Research Assn.
Centriline Corp.
Inertol Co., Inc.
Reilly Tar & Chemical Corp.

Pipe Cutters:
James B. Clow & Sons
Ellis & Ford Mfg. Co.
Jos. G. Pollard Co., Inc.
Reed Mfg. Co.
A. P. Smith Mfg. Co.
Spring Load Mfg. Corp.

Pipe Jointing Materials; see Jointing Materials

Pipe Locators:
W. S. Darley & Co.
Jos. G. Pollard Co., Inc.

Pipe Vises:
Spring Load Mfg. Corp.

Plugs, Removable:
James B. Clow & Sons
Jos. G. Pollard Co., Inc.
A. P. Smith Mfg. Co.

Potassium Permanganate:
Carus Chemical Co.

Pressure Regulators:
Allis-Chalmers Mfg. Co.
Foster Eng. Co.
Golden-Anderson Valve Specialty Co.
Mueller Co.
Ross Valve Mfg. Co.

Pumps, Boiler Feed:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.

Pumps, Centrifugal:
Allis-Chalmers Mfg. Co.
American Well Works
DeLaval Steam Turbine Co.
Morse Bros. Mchy. Co.
C. H. Wheeler Mfg. Co.

Pumps, Chemical Feed:
Infilco Inc.
Proportioneers, Inc. (Div., B-I-F Industries)
Wallace & Tiernan Inc.

Pumps, Deep Well:
American Well Works
Layne & Bowler, Inc.

Pumps, Diaphragm:
Dorr-Oliver Inc.
Morse Bros. Mchy. Co.
Wallace & Tiernan Inc.

Pumps, Hydrant:
W. S. Darley & Co.
Jos. G. Pollard Co., Inc.

Pumps, Hydraulic Booster:
Ross Valve Mfg. Co.

Pumps, Sewage:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.
C. H. Wheeler Mfg. Co.

Pumps, Sump:
DeLaval Steam Turbine Co.
C. H. Wheeler Mfg. Co.

Pumps, Turbine:
DeLaval Steam Turbine Co.
Layne & Bowler, Inc.

Recorders, Gas Density, CO_2, NH_3, SO_2, etc.:
Permutit Co.
Wallace & Tiernan Inc.

Recording Instruments:
Builders-Providence, Inc. (Div., B-I-F Industries)
Fischer & Porter Co.
Infilco Inc.
Minneapolis-Honeywell Regulator Co.
Wallace & Tiernan Inc.

Reservoirs, Steel:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
R. D. Cole Mfg. Co.
Graver Water Conditioning Co.
Hammond Iron Works
Pittsburgh-Des Moines Steel Co.

Sand Expansion Gages; see Gages

Sleeves; see Clamps

Sleeves and Valves, Tapping:
James B. Clow & Sons
M & H Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.

Sludge Blanket Equipment:
General Filter Co.
Graver Water Conditioning Co.
Permutit Co.

Sodium Aluminate:
Monolith Portland Midwest Co.

Sodium Chloride:
Frontier Chemical Co.

Sodium Hexametaphosphate:
Calgon, Inc.

Sodium Hypochlorite:
John Wiley Jones Co.
Wallace & Tiernan Inc.

Sodium Silicate:
Philadelphia Quartz Co.

Softeners:
Cochrane Corp.
Dorr-Oliver Inc.
General Filter Co.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
Infilco Inc.
Permutit Co.
Roberts Filter Mfg. Co.
Walker Process Equipment, Inc.

Softening Chemicals and Compounds:
Calgon, Inc.
Cochrane Corp.
General Filter Co.
Infilco Inc.
Morton Salt Co.
Permutit Co.
Tennessee Corp.

Standpipes, Steel:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
R. D. Cole Mfg. Co.
Graver Water Conditioning Co.
Hammond Iron Works
Pittsburgh-Des Moines Steel Co.

Steel Plate Construction:
Alco Products, Inc.
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
R. D. Cole Mfg. Co.
Graver Water Conditioning Co.
Hammond Iron Works
Pittsburgh-Des Moines Steel Co.

Stops, Curb and Corporation:
Hays Mfg. Co.
Mueller Co.

Storage Tanks; see Tanks

Strainers, Suction:
James B. Clow & Sons
M. Greenberg's Sons
Johnson, Edward E., Inc.
R. D. Wood Co.

Here's how an "accident" proved the ruggedness of the

F & P CHLORINATOR

Here's a true story of how one user decided the modern, rugged Fischer & Porter Chlorinator was his best buy.

"I was impressed with the F&P Chlorinator the minute your field engineer arrived."

"He pulled up to a loading dock in a truck and began to unload the chlorinator. When he had it at the back of the truck, he stopped and got back inside the cab as if to get something and then 'accidentally' let the clutch slip. The truck shot forward and the chlorinator toppled off the back of the truck and onto the cement floor."

"For a moment we all thought the equipment would smash into a hundred pieces—but it didn't. That just about sold us on it. Of course, we now realize the 'accident' was all part of the demonstration to show us how tough the F&P Chlorinator is."

No other chlorinator is built this way. No other chlorinator can take such punishment. The light weight, fibre glass cabinet is so rugged even such an "accident" won't harm it.

And what's more this is only one true story of user satisfaction with F&P Chlorinators. Everywhere users are adding their words of praise for this chlorinator.

In addition to the ruggedness of the unit, you get simplified operation, the absolute minimum of maintenance costs. As one user puts it, "We shudder at the thought of overhauling other chlorinator units, but it's a pleasure to bring the F&P unit into the shop. We know it will need very little maintenance work—and any work it does need will be 'child's play' compared to the time and back-breaking labor spent on other chlorinators.

Users are saying these things. If you're not completely acquainted with the Fischer & Porter Chlorinator now is the time to get complete information. It won't cost you a penny, you won't be obligated in any way . . . and if you like we will arrange an on-the-spot demonstration for you anytime, anywhere. Write today for details. Fischer & Porter Company, 966 Fischer Road, Hatboro, Penna.

Surface Wash Equipment:
Cochrane Corp.
Permutit Co.

Swimming Pool Sterilization:
Builders-Providence, Inc. (Div., B-I-F Industries)
Fischer & Porter Co.
Omega Machine Co. (Div., B-I-F Industries)
Proportioneers, Inc. (Div., B-I-F Industries)
Wallace & Tiernan Inc.

Tanks, Steel:
Alco Products, Inc.
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
R. D. Cole Mfg. Co.
Graver Water Conditioning Co.
Hammond Iron Works
Pittsburgh-Des Moines Steel Co.

Tapping-Drilling Machines:
Hays Mfg. Co.
Mueller Co.
A. P. Smith Mfg. Co.

Tapping Machines, Corp.:
Hays Mfg. Co.
Mueller Co.

Taste and Odor Removal:
Builders-Providence, Inc. (Div., B-I-F Industries)
Cochrane Corp.
General Filter Co.
Graver Water Conditioning Co.
Industrial Chemical Sales Div.
Infilco Inc.
Permutit Co.
Proportioneers, Inc. (Div., B-I-F Industries)
Wallace & Tiernan Inc.

Tenoning Tools:
Spring Load Mfg. Corp.

Turbidimetric Apparatus (For Turbidity and Sulfate Determinations):
Wallace & Tiernan Inc.

Turbines, Steam:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.

Turbines, Water:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.

Valve Boxes:
James B. Clow & Sons
Ford Meter Box Co.
M & H Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.
Trinity Valley Iron & Steel Co.
R. D. Wood Co.

Valve-Inserting Machines:
Mueller Co.
A. P. Smith Mfg. Co.

Valves, Altitude:
Golden-Anderson Valve Specialty Co.
Ross Valve Mfg. Co., Inc.
S. Morgan Smith Co.

Valves, Butterfly, Check, Flap, Foot, Hose, Mud and Plug:
Builders-Providence, Inc. (Div., B-I-F Industries)
Chapman Valve Mfg. Co.
James B. Clow & Sons
DeZurik Shower Co.
M. Greenberg's Sons
Kennedy Valve Mfg. Co.
M & H Valve & Fittings Co.
Mueller Co.
Henry Pratt Co.
Rensselaer Valve Co.
S. Morgan Smith Co.
R. D. Wood Co.

Valves, Detector Check:
Hersey Mfg. Co.

Valves, Electrically Operated:
Builders-Providence, Inc. (Div., B-I-F Industries)
Chapman Valve Mfg. Co.
James B. Clow & Sons
Crane Co.
Darling Valve & Mfg. Co.
Golden-Anderson Valve Specialty Co.
Kennedy Valve Mfg. Co.
M & H Valve & Fittings Co.
Mueller Co.
Philadelphia Gear Works, Inc.
Henry Pratt Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.
S. Morgan Smith Co.

Valves, Float:
James B. Clow & Sons
Golden-Anderson Valve Specialty Co.
Henry Pratt Co.
Ross Valve Mfg. Co., Inc.

Valves, Gate:
Chapman Valve Mfg. Co.
James B. Clow & Sons
Crane Co.
Darling Valve & Mfg. Co.
Dresser Mfg. Div.
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

Valves, Hydraulically Operated:
Builders-Providence, Inc. (Div., B-I-F Industries)
Chapman Valve Mfg. Co.
James B. Clow & Sons
Crane Co.
Darling Valve & Mfg. Co.
DeZurik Shower Co.
Golden-Anderson Valve Specialty Co.
Kennedy Valve Mfg. Co.
F. B. Leopold Co.
M & H Valve & Fittings Co.
Mueller Co.
Philadelphia Gear Works, Inc.
Henry Pratt Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.
S. Morgan Smith Co.
R. D. Wood Co.

Valves, Large Diameter:
Chapman Valve Mfg. Co.
James B. Clow & Sons
Crane Co.
Darling Valve & Mfg. Co.
Golden-Anderson Valve Specialty Co.
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
Henry Pratt Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.
S. Morgan Smith Co.
R. D. Wood Co.

Valves, Regulating:
DeZurik Shower Co.
Foster Eng. Co.
Golden-Anderson Valve Specialty Co.
Minneapolis-Honeywell Regulator Co.
Mueller Co.
Henry Pratt Co.
Ross Valve Mfg. Co.
S. Morgan Smith Co.

Valves, Swing Check:
Chapman Valve Mfg. Co.
James B. Clow & Sons
Crane Co.
Darling Valve & Mfg. Co.
Golden-Anderson Valve Specialty Co.
M. Greenberg's Sons
M & H Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

Venturi Tubes:
Builders-Providence, Inc. (Div., B-I-F Industries)
Infilco Inc.
Simplex Valve & Meter Co.

Waterproofing:
Barrett Div.
Inertol Co., Inc.

Water Softening Plants; see Softeners

Water Supply Contractors:
Layne & Bowler, Inc.

Water Testing Apparatus:
Wallace & Tiernan Inc.

Water Treatment Plants:
American Well Works
Chain Belt Co.
Chicago Bridge & Iron Co.
Cochrane Corp.
Dorr-Oliver Inc.
Fischer & Porter Co.
General Filter Co.
Graver Water Conditioning Co.
Hammond Iron Works
Hungerford & Terry, Inc.
Infilco Inc.
Permutit Co.
Pittsburgh-Des Moines Steel Co.
Roberts Filter Mfg. Co.
Walker Process Equipment, Inc.
Wallace & Tiernan Inc.

Well Drilling Contractors:
Layne & Bowler, Inc.

Well Screens:
Johnson, Edward E., Inc.

Wrenches, Ratchet:
Dresser Mfg. Div.

Zeolite; see Ion Exchange Materials

A complete Buyers' Guide to all water works products and services offered by AWWA Associate Members appears in the 1955 AWWA Directory.

IMPROVE Water Treatment with PROVED American EQUIPMENT

CONTINUOUS PIPELINE CHEMICAL MIXING

THE HOMOMIX—provides instant, violent, uniform, and complete mixing of one or more chemicals or gases with water—continuously or intermittently, *without the use of a mixing tank!* Designed with one or more stages of direct-connected motor driven diffuser impellers rotating in blending chambers, it forms part of the influent piping. Discharges directly across the flow-through stream. Mixes instantaneously at the point of entry. Lift impeller can be added to provide additional head, if required. *Send for Technical Supplement HM and Bulletin 300.*

IRON AND CARBON DIOXIDE REMOVAL

THE FERROFILTER—removes iron, manganese, carbon dioxide, and other dissolved gases and odors—efficiently and economically, in one simple operation. Utilizes fine media in open aeration. *Write for Bulletin No. 252B.*

SOFTENING AND TURBIDITY REMOVAL

THE FLOCSETTLER—combines in one unit all modern concepts of water and waste treatment, including mixing and slurry blending, slurry recirculation, sludge blanket settling, sludge concentration, and sludge removal. *Send for Technical Supplement FL.*

RAPID MIX AND FLOCCULATION UNITS

PADDLE-PROPELLER-RM TYPE MIXERS—for rapid mixing to obtain continuous blending of chemical with raw water.

PADDLE-DOWNFLO-FLOCCULATION UNITS—designed to efficiently carry out the slow mixing and flocculation functions required in the coagulation process. Choice of vertical and horizontal units. *Send for Technical Supplement PF.*

SLUDGE REMOVAL

POSITIVE FLIGHT CONVEYORS—for rectangular settling tanks. Heavy-duty solid shafting, babbitted plate sprockets. Heavy adjustable self-aligning wall bearings, furnished with foundation bolts welded to templates and eccentric washers for economical installation.

CIRCULAR CLARIFIERS—Structural steel bridge, steel flights in staggered position mounted on two radial trussed arms driven by motorized gear reduction unit. *Write for Bulletin 253B.*

PUMPS

Complete line of double-suction split-case single-stage, two-stage, end suction, axial flow, sludge, and deep well turbine pumps—for wide range of raw water, low lift, high lift, backwash, and general service pumping requirements. *Send for Bulletins 248A, 246A, 251A, 245A.*

Utilize our experience in engineering design and manufacture of field-proved equipment and pumps for water and waste treatment.

AMERICAN WELL WORKS

IN OUR 88TH YEAR
112 North Broadway
AURORA, ILLINOIS

Pumping, Sewage Treatment, and Water Purification Equipment
RESEARCH • ENGINEERING • MANUFACTURING

Offices: Chicago • New York • Cleveland • Cincinnati • Kansas City • Sales Representatives throughout the World

Behind these doors...

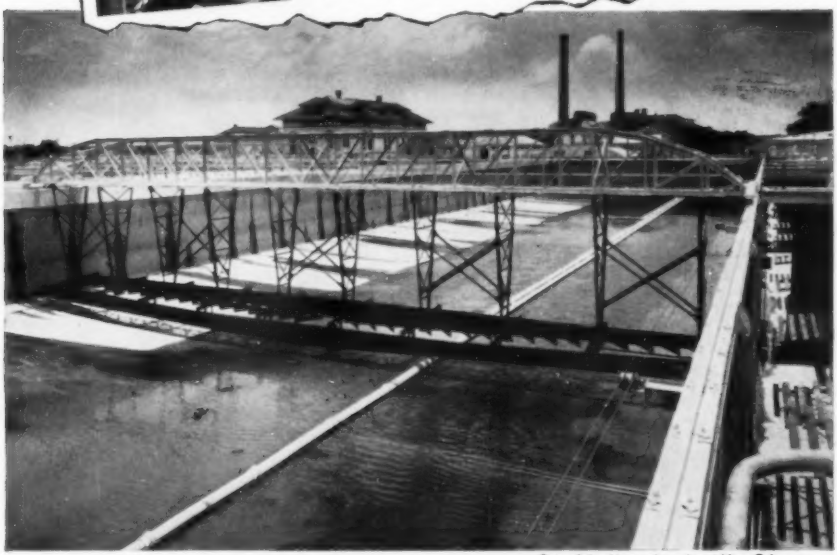
is the water meter of tomorrow!

What features do you want in tomorrow's water meter? Do you want fewer parts . . . fewer leaks . . . less friction and wear . . . non-fogging registers . . . greater accuracy . . . easier repairs? Then look to Rockwell Research and Development to show the way. For Rockwell alone, with its diversity of interests, has the wealth of engineering talent, plus the knowledge and facilities to bring you this better meter of tomorrow.

Rockwell Manufacturing Company
Pittsburgh 8, Pa.

Water Treatment, too, needs
INDIVIDUAL DIAGNOSIS

No two water treatment problems are exactly alike. The right solution to each can only be arrived at after a careful study of the local conditions. Variables such as raw water composition, rate of flow and results required automatically rule out the cure-all approach. The installation shown below is a good example of how equipment should be selected to fit the job . . . and not vice versa.



One of the Monorake units at New Orleans

New Orleans
LOUISIANA

Completes Expansion Program with 200 MGD Conventional Water Treatment Plant

New Orleans started its water plant expansion program with the installation of twelve Dorrco Hydro-Treator mechanisms . . . six each in two existing basins with the basins operating in parallel at 50 MGD each. This gave the City immediate high-rate softening and clarification capacity for 100 MGD.

It recently completed its program with a conventional treatment plant with 200 MGD capacity. Following chemical pretreatment, clarification is carried out in two rectangular basins which were part of the original plant. Each basin is now equipped with a Dorrco Monorake 106′ 6″ wide with lengths of 477′ and 508′.

If you'd like more information on the complete line of Dorr-Oliver water treatment equipment, write for Bulletin No. 9141 to Dorr-Oliver Incorporated, Stamford, Connecticut.

Hydro-Treator and Monorake T.M. Reg. U. S. Patent Office.

Every day over 8½ billion gallons of water are treated by Dorr-Oliver equipment.

DORR-OLIVER
INCORPORATED
WORLD-WIDE RESEARCH • ENGINEERING • EQUIPMENT
STAMFORD • CONNECTICUT • U.S.A.

LEADITE

Trade Mark Registered U. S. Pat. Office

Jointed for . . . Permanence with LEADITE

Generally speaking, most Water Mains are buried beneath the Earth's surface, to be forgotten,—they are to a large extent, laid for permanency. Not only must the pipe itself be dependable and long lived,—but the joints also must be tight, flexible, and long lived,—else leaky joints are apt to cause the great expense of digging up well-paved streets, beautiful parks and estates, etc.

Thus the "jointing material" used for bell and spigot Water Mains MUST BE GOOD,—MUST BE DEPENDABLE,—and that is just why so many Engineers, Water Works Men and Contractors aim to PLAY ABSOLUTELY SAFE, by specifying and using LEADITE.

Time has proven that LEADITE not only makes a tight durable joint,—but that it improves with age.

The pioneer self-caulking material for c. i. pipe.
Tested and used for over 40 years.
Saves at least 75%

THE LEADITE COMPANY
Girard Trust Co. Bldg. Philadelphia, Pa.

No Caulking